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THE PRODUCTS

of the

C. H. WHEELER MANUFACTURING CO.

INCLUDE:

SURFACE CONDENSERS

Standard High Transmission Condensers
Water Works Condensers

JET CONDENSERS

Low Level Jet Condensers
Counter Current Barometric Condensers

VACUUM PUMPS

Direct Acting Vacuum Pumps
Mullan Vacuum Pumps
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COOLING TOWERS

Natural Draft Water Cooling Towers
Forced Draft Water Cooling Towers

"Everything but the Turbine"

INTRODUCTION

The advent of the steam turbine, operating either high pressure or completing the expansion of steam begun in a reciprocating engine, has brought with it the demand for high vacuum. The necessity of producing vacua of 28 and 29 inches within reasonable limits of size and operating cost has revolutionized condenser practice, with the result that modern condensing machinery is far ahead of that of a few years ago.

As the function of a condenser is to increase the economy of a power plant, it follows that the selection of the most suitable apparatus is by no means merely a question of first cost.

The important points to be considered are *economy in maintenance charges, low operating cost and reliability.* Operating cost is a very large item and differs widely with different types of condensers, viz., Jet, Barometric and Surface. Other points to be considered are the load factor of the turbine or engine, the cost and net lift of the water used, the location of the plant and the use or non use of a water cooling tower. As explained in another chapter, the cooling tower may frequently prove the deciding factor in the choice of a condenser.

Condensers of the same general type necessitate the consideration of the counter-current principle, arrangement of tubes and baffles, direction of flow of the steam, together with the type and efficiency of the feed water heater, all of which affect the economy of the performance.

Guided by many years of experience and specialization in condenser engineering the C. H. WHEELER MANUFACTURING COMPANY has developed the "High Efficiency" steam auxiliaries described in the following pages, which include the entire auxiliary equipment of a modern steam power plant.

C. H. WHEELER Condensers are built in a variety of types to meet individual requirements. Before making any recommendation, the conditions affecting the particular installation are carefully studied and the order is entered only for such equipment as will insure satisfactory performance. This is one reason for the uniformly high economy realized with C. H. WHEELER apparatus.

Every machine bearing the name of C. H. WHEELER is designed for efficiency, simplicity, reliability and general ruggedness of appearance. The ratings are conservative and the performance of each unit is guaranteed on the basis of careful shop tests.

Special attention is invited to the THYSSEN ENTRAINMENT VACUUM PUMPS, which embody the result of years of painstaking research and development, enabling the C. H. WHEELER MANUFACTURING COMPANY to offer an apparatus standing foremost among entrainment pumps, both in regard to design and efficiency.

MR. C. H. WHEELER and his staff have devoted their entire time and efforts, and for a period of over a quarter of a century, to the branch of steam engineering covered by the within. No concern in the United States or abroad has given the subject of condensers and their auxiliaries more study or attention, and with greater success.

The C. H. WHEELER MANUFACTURING COMPANY employ a large organization of engineers competent to deal with any problem that may arise in connection with their specialties. Each equipment, from the time the order is received and until it is in satisfactory commercial operation, is given individual attention.

Realizing that the advent of the steam turbine and high vacuum condensing equipment has introduced conditions with which many operating engineers are frequently not familiar, the C. H. WHEELER MANUFACTURING COMPANY make it a practice to have one of their experts start up and thoroughly instruct the operating force as to the proper care of the apparatus and the best means to obtain the highest efficiency.

The Plant of the C. H. Wheeler Manufacturing Company is located in Philadelphia, the best labor market in the United States. It is equipped with electrically operated machine tools and up-to-date facilities, permitting the largest size condensers and pumps to be machined, assembled and tested within the Works.

In addition to the Works, the Engineering Department and Head Sales Office are located in Philadelphia; with branch Sales Offices in New York, Boston, Pittsburgh, Cleveland, Cincinnati, Chicago, Charlotte, New Orleans and San Francisco.

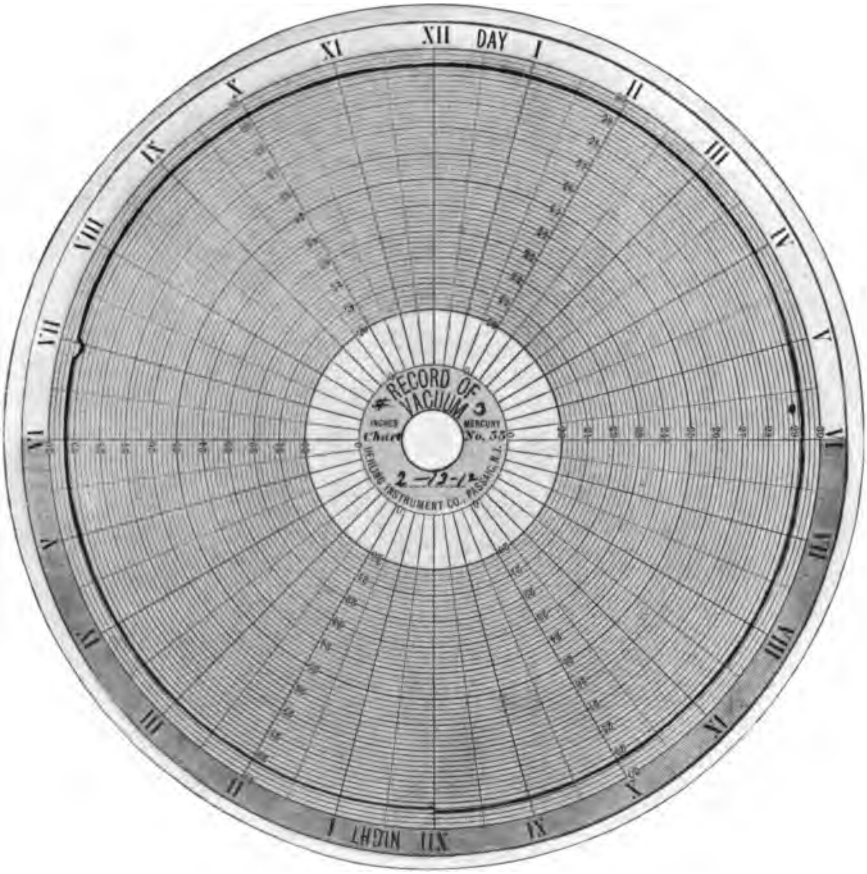


FIG. I.

Chart from recording vacuum gauge connected to 2500 KW. Turbine with C. H. WHEELER Surface Condenser and "ROTREX" Vacuum Pump. This curve, which shows a vacuum of about 29.3 inches, was taken in winter and indicates the vacuum possible under cold water conditions.

CHAPTER I

ECONOMY OF HIGH VACUUM

Roughly speaking a given weight of steam does the same amount of work by expanding to double its volume, whatever may be the pressure at which it starts to expand. Whether it starts at 150 pounds absolute and doubles its volume by expanding to 75 pounds, or whether we consider its expansion from 2 pounds absolute pressure; *i.e.*, 26 inches of vacuum to 1 pound absolute; or 28 inches of vacuum, the work done is virtually the same.

Were the steam to expand isothermally, the foregoing would be literally, not approximately, true, because it would follow Boyle's law.

Pressure x Volume = Constant.

The actual expansion curve, however, is lower; even slightly lower than the adiabatic curve, owing to the condensation resulting from expansion and radiation. We may say, nevertheless, that *each time the volume is doubled, an equal amount of work is performed.*

The practical importance of the above lies in the fact that, under ordinary conditions. about one-half of the energy contained in the steam is lost by exhausting at atmospheric pressure, *i.e., as much work can be extracted from the steam below the atmospheric line as above it.* This will be seen from Fig. 2, in which the adiabatic curve is plotted from 165 pounds to .5 pound absolute; viz., 29 inches of vacuum. The area A B C of the curve above the atmospheric pressure line is about equal to the area B C D E F B below the atmospheric line. Each time the steam doubles its volume, as from F to G, G to H, etc., the same amount of work is performed.

ECONOMY OF HIGH VACUUM

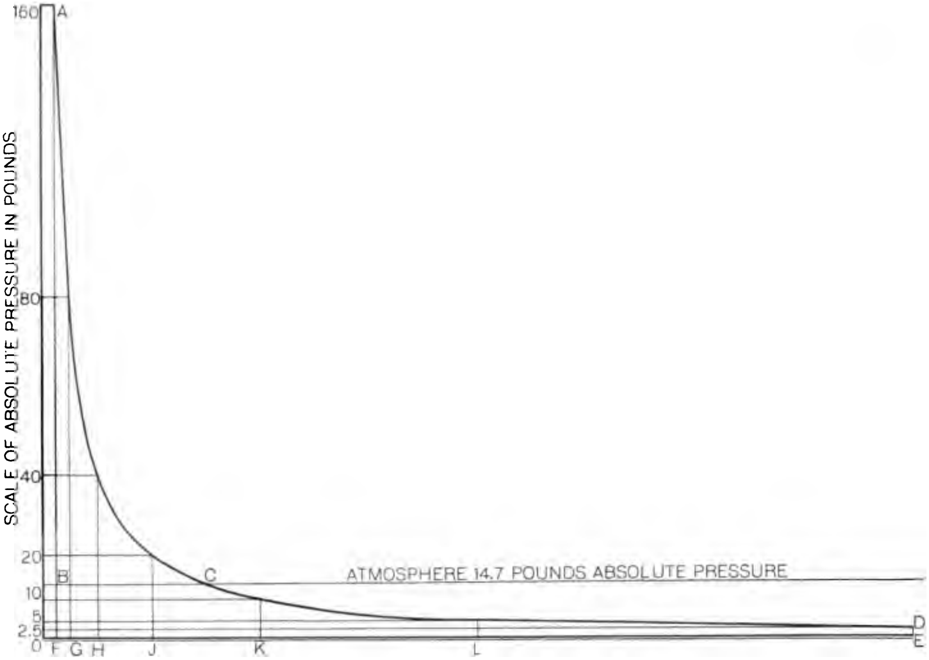


FIG. 2.

Progress toward utilizing the energy of steam under high vacua was long impeded due to the impracticability of expanding steam in reciprocating engines below 25 inches of vacuum on account of the excessive size of the low pressure cylinders required. In other words, the high cost, internal friction and condensation losses involved with the utilization of the last few inches of vacuum, more than offset the amount of energy which might otherwise be gained. The advent of the steam turbine, which brought about so many radical changes in the design of power machinery, also revolutionized condenser practice. For the steam turbine attains its highest efficiency with steam at moderate pressure, the energy of which it converts into useful work just as the reciprocating engine develops its best efficiency when utilizing the energy of steam at high pressure. This recognition has led to the adoption in existing plants of low pressure turbines receiving the exhaust steam of reciprocating engines at atmospheric pressure and allowing it to expand to 28 inches of vacuum and beyond. Where formerly an engine operated noncondensing it is now possible to add 75 per cent. or more to the power derived from the steam, after making due allowance for the power required to operate the condenser auxiliaries. With a compound engine condensing at 25 inches of vacuum, the net output per pound of fuel may be increased from 20 to 30 per cent., by lengthening the cut-off and exhausting at atmospheric pressure into a low pressure turbine. The combined cost of the turbine, condenser and auxiliaries would still be less than the cost of an additional engine and boiler, not counting the saving in fuel.

The percentage of fuel saved for each of the last few inches of vacuum varies slightly with different types of turbines, and ranges from 4 to 6 per cent. per inch from 25 to 29 inches. The foregoing shows the great enconomic value of high vacuum. A striking proof of the progress in condenser efficiency may be found in the performance of many recent plants which, under cold water conditions, are able to produce vacua of 1 inch absolute, and better.

To produce high vacuum under ordinary operating conditions and with a moderate quantity of cooling water, it is essential to so design and dimension the condenser as to remove the maximum amount of heat units per pound of cooling water, *i.e.,* to raise the temperature of the cooling water as nearly as possible to that corresponding to the vacuum. Under favorable test conditions it is possible to obtain a better performance from the condenser than can be expected year in and year out under ordinary operating conditions. For this reason a condenser should be rated with due allowance for local conditions rather than its performance under ideal test conditions.

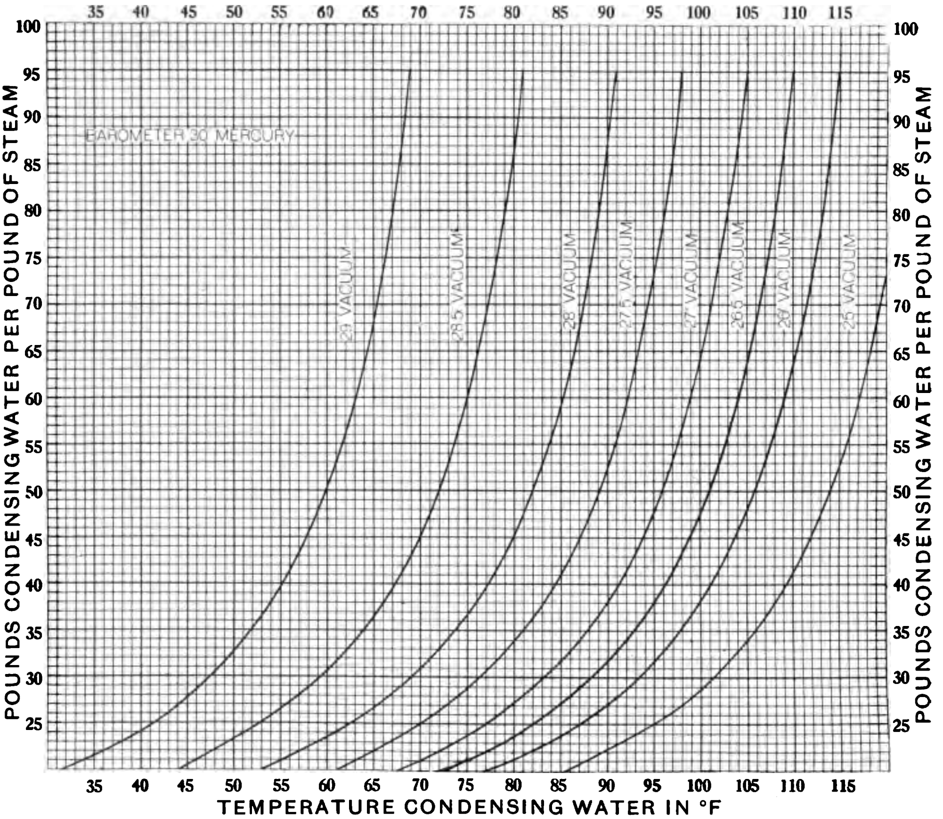


FIG. 3.

Diagram showing theoretical ratio of injection water to steam for different vacua and water temperatures. To use the diagram, add the desired terminal difference to the temperature of the injection water, and read up from the corresponding point on the base line to the proper vacuum curve. The ratio appears at the left. For example, for 70 degrees water, 15 degrees terminal difference and 28-inch vacuum, read up from 85 degrees, intersecting the 28-inch vacuum curve at a point corresponding to the ratio of 59 to 1. These curves are intended for turbines or engines using saturated steam at the throttle.

CHAPTER II

THERMODYNAMICS OF CONDENSERS

To condense steam, its latent heat of evaporation must be transferred to a sufficient weight of water cold enough to absorb the heat. At 90 degrees Fahrenheit, for example, which corresponds to an absolute pressure of 1.42 inches of mercury or 28.58 inches of vacuum referred to a 30-inch barometer, steam contains about 1040 latent heat units (B. T. U's.) per pound. If this heat is transferred to water entering the condenser at 60 degrees and the water thereby heated to 90 degrees, which is the utmost possible with 90-degree steam, each pound of water will absorb 30 B. T. U's.* Therefore, for each pound of steam condensed there will be required

$$\frac{1040}{30} = 34.7$$

pounds of water as the least quantity theoretically possible to condense the steam.

If the water enters at 70 degrees, each pound can only absorb 20 B. T. U. and

$$\frac{1040}{20} = 52$$

pounds of water will be required per pound of steam. For example, suppose we take a 10,000 KW. turbine, or engine-and-turbine plant, using 15 pounds of steam per KW. per hour. If the average summer temperature of the cooling water is 70 degrees, and a vacuum temperature of 90 degrees is specified at that season, then

$$\frac{10{,}000 \text{ x } 15 \text{ x } 1040}{20} = 7{,}800{,}000$$

pounds of cooling water per hour will theoretically be required.

---

*A British Thermal Unit (B. T. U.) is the quantity of heat required to raise the temperature of one pound of water 1 degree Fahrenheit.

THERMODYNAMICS OF CONDENSERS

As the cooling water, in actual practice, never rises fully to the temperature of the vacuum, it is necessary in the calculation to allow for a certain temperature difference between the outgoing water and the vacuum. In most instances condensers are designed for a difference or "Temperature Head" of 5 degrees Fahrenheit and over, depending on the vacuum and on the temperature of the incoming water, but being greater for a low vacuum (where less water is handled) than for a high vacuum, and greater in winter than in summer. In practice the condenser is designed for average summer conditions, and in winter produces a much higher vacuum.

Owing to condensation in the turbine, due partly to radiation and to expansion, the steam exhausted into the condenser contains invariably a small amount of moisture (pre-condensation) ranging from 1 to 10 per cent.; in other words, the steam gives up part of its latent heat before it enters the condenser. It is therefore sufficiently accurate to assume that the condenser receives 950 B. T. U. per pound of steam used at the throttle when the latter reaches the turbine saturated, and 1000 B. T. U. per pound when it is moderately superheated.

It is obvious that the smallest quantity of water will be required when the cooling water leaves the condenser at a temperature as close as possible to that of the vacuum; hence, as power is required to handle the cooling water, the provisions made for utilizing the water as completely as possible constitute an important feature of modern condenser design.

No condenser produces a perfect vacuum. A closed vessel exhausted completely of air, and partially filled with water, contains water vapor whose pressure or "tension" will depend on its temperature. This pressure is that shown in tables of saturated steam. For a temperature of 60 degrees Fahrenheit it is .52 inch of mercury, or 29.48 inches of vacuum referred to 30-inch barometer; for 80 degrees, 1.029 inches of mercury; for 100 degrees, 1.926 inches, and so on. (See Marks and Davis—*Steam Tables and Diagrams.*) In a steam condenser, however, there is always present a certain amount of air in addition to the water vapor. Some of this is carried through with the steam from the feed water; a large quantity is added by leaks around the piston rod and valve stem of the low pressure cylinder, when reciprocating engines are used, or it is admitted through the shaft stuffing boxes of turbines, also by air leaks in the joints of the exhaust pipe. In the jet type of condenser a third source of air, larger than either of the others, is the cooling water itself, whose absorbed air is set free by the reduced pressure and increased temperature in the condenser.

Relation of Air and Vapor in the Condenser

Before entering on a detailed study of the several types of condensers and their pumps it is well to have a clear idea of the nature and behavior of the mixture of air and water vapor.

In the first place we must keep in mind that although it is common to talk about the air pump, as if it were responsible for the vacuum, in reality it is the condenser, not the air pump, which produces the vacuum. The pump has merely to remove the air which leaks or is carried in (with or without the condensed steam)—in other words, it preserves the vacuum already created from being gradually impaired. If a "dry air" pump, handling air and vapor alone, is shut down, a tight condenser will still operate for a considerable length of time with no change except a slight drop in vacuum. Therefore, although efficient pumps are important, the heat removing ability of the condenser itself remains the vital factor.

Air in a condenser is highly undesirable, as it not only demands work for its removal but seriously cuts down the efficiency of the condenser, owing to its low thermal conductivity. Furthermore, any pump which takes air from the condenser must necessarily remove water vapor with the air. The vacuum is not benefited by pumping out this vapor, as the pressure of the latter in the condenser is determined by the temperature, and any vapor removed is instantly replaced. Nevertheless vapor must be handled in order to get rid of the air. Hence it is highly desirable to minimize the quantity of air,—in other words, to detect and eliminate existing air leaks, as the air absorbed in the feed and cooling water cannot be avoided. As will later be seen, the work of the vacuum pump can be further lessened by taking the air and water vapor from the coldest part of the condenser, thereby reducing the vapor tension and removing the air in a less rarefied state. This refers more particularly to displacement types of pumps, since entrainment pumps condense instantly the vapor reaching them, and cool the air, so that they are little affected by the percentage of the former in the mixture handled.

Owing to the presence of air, the absolute pressure in a condenser is always greater than that due to the temperature and pressure of the water vapor alone. For example: Supposing the hot well temperature in a jet condenser to be 90 degrees Fahrenheit, if no air were present the absolute pressure would be 1.42 inches of mercury, or a vacuum of 28.58 inches referred to a 30-inch barometer. If the actual vacuum is 28 inches at that temperature the excess pressure of .58 inch of mercury is due to air. This is in accordance with Dalton's Law, teaching that *when two gases or vapors are mixed in a given space, the resulting pressure is the sum of the partial pressures which each gas or vapor would exert if it occupied the given space alone.*

In this manner the partial air pressure, and consequently the quantity of air present, can readily be determined by subtracting from the absolute pressure actually existing in the condenser the pressure indicated by the steam tables, corresponding to the temperature measured in the vacuum space.

If the volume of the steam space in the condenser be known, the quantity of air actually present may be calculated from its partial pressure as follows:

The volume of one pound of dry air at 32 degrees Fahrenheit and 30-inch barometer is 12.38 cubic feet. This volume increases at the rate of

$$\frac{1}{460+32}$$

for each degree of rise in temperature; thus at 90 degrees Fahrenheit the volume is

$$12.38 \times \frac{460+90}{460+32} = 13.84$$

cubic feet. At 90 degrees condenser temperature the partial pressure due to the steam is 1.42 inches of mercury, leaving .58 inch for the partial pressure due to the air in the case assumed above. At this pressure a pound of air will occupy

$$\frac{13.84 \times 30}{.58} = 717$$

cubic feet. Comparing this volume with that of the interior of the condenser, the weight of air present is readily calculated.

The air carried into the condenser with the feed water may be neglected, as its volume is so small compared to that due to leakage past the stuffing boxes and glands of the low-pressure engine cylinder or turbine, exhaust pipe joints, etc. The latter cannot be calculated, as it varies according to the care used by the operating engineer.

The air released in a jet condenser by the cooling water, due to the reduction of pressure on the latter and its rise in temperature, exceeds considerably the air entering a well-built surface condenser by leakage; consequently the air pump for a jet condenser must be considerably larger than that for a surface condenser of equal capacity. Although the quantity of free air carried in is in any case small, it expands to many times its atmospheric volume on reaching the condenser, and the enlarged volume, not the atmospheric volume, must be handled by the pump.

It has already been remarked that the work of a displacement vacuum pump may be materially lightened by cooling the air-vapor mixture as much as possible, by exposing it to the incoming cooling water, before removing it from the condenser.

Although the air is reduced slightly in volume by this process, the principal benefit is that the useless water vapor is partly condensed and greatly reduced in volume, so that a cubic foot of the "refrigerated" mixture contains a much greater weight of air. To illustrate, suppose the condenser temperature to be 90 degrees and the condenser pressure 2 inches absolute, also that the temperature of the cooling water is 55 degrees, and that the mixture is reduced to 60 degrees before going to the air pump. As pointed out, at 90 degrees the partial pressure of the air is only .58 inch, leaving 1.42 inch for the partial pressure of the vapor pumped with the air. At 60 degrees the partial pressure due to the vapor is only .52 inch, and as the total pressure is still that of the condenser itself, or 2 inches, it follows that the partial pressure of the air will be 1.48 inches, thus almost reversing the relative quantities of vapor and air and nearly trebling the weight of air handled per stroke of the pump.

Although it is desirable to cool the air and water vapor as much as possible before withdrawing them from the condenser, it is evident that the condensate, to be returned at once to the boiler, should be cooled as little as possible. In a large surface condenser this is accomplished by withdrawing the air and condensate separately, the former after it has been cooled by contact with the coldest tubes, the latter with as little tube contact as possible after condensation has occurred. By running the hot well pump under a head, and by minimizing the pipe friction between the hot well and the pump, it is found to be unnecessary to cool the condensate in order to avoid re-evaporation in the hot well pump. In plants of moderate size, it is usually better to compromise in the matter of final temperatures, and to remove both air and water with a single pump, which is more reliable than the smaller separate pumps would be. When separate pumps are employed, the system is described as "wet and dry"; where one pump handles both air and water the term "wet" system is used.

The water in the "wet" system serves a useful purpose in sealing the piston and valves against air leakage, also in absorbing the heat generated by compressing the air to atmospheric pressure. With the "wet and dry" system it is highly desirable to employ an air pump so arranged that a small stream of water can be fed into the suction, both for sealing purposes and to reduce the vapor tension of the mixture as much as possible.

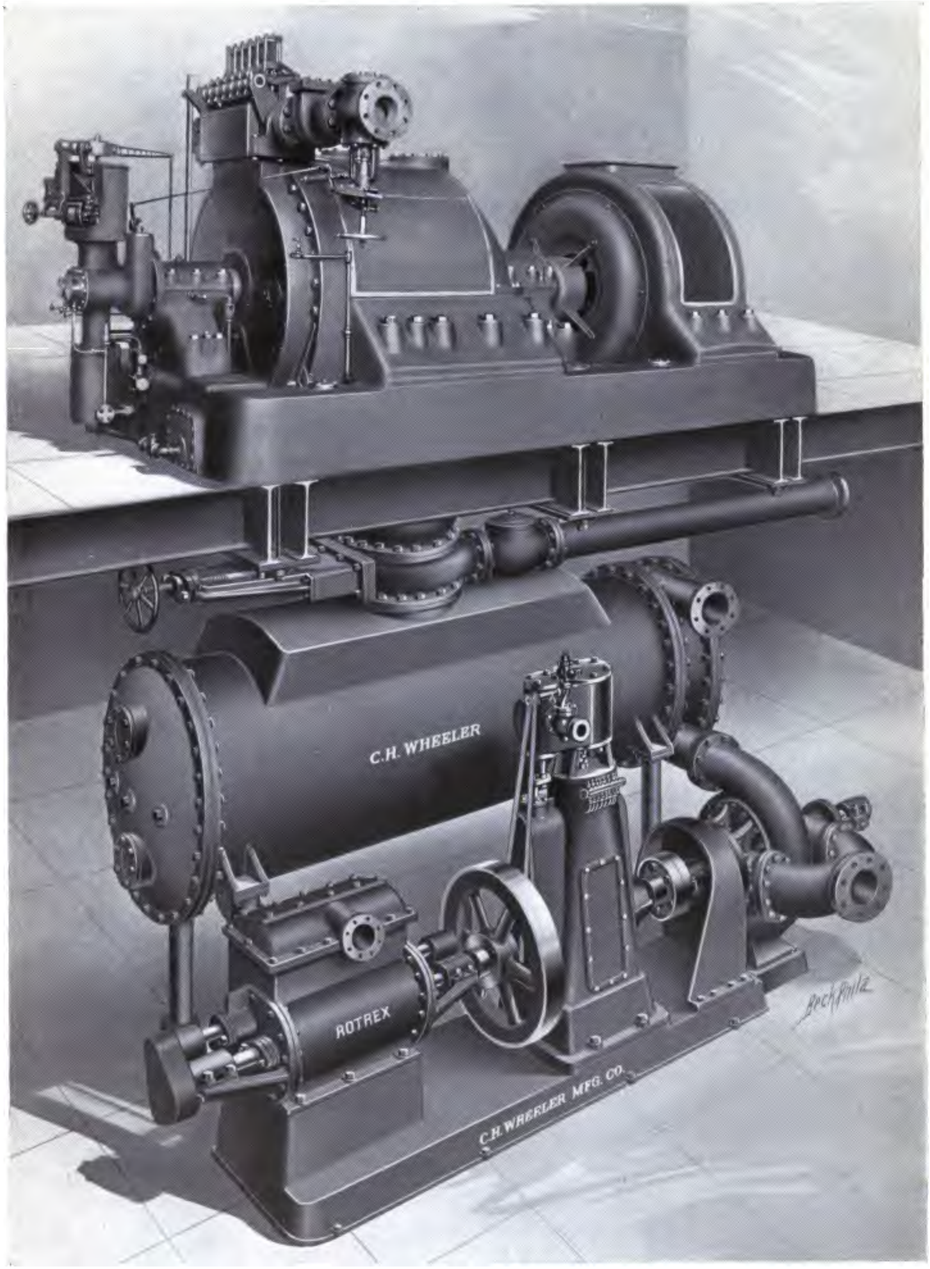


FIG. 4.

Steam Turbo-Generator with Surface Condenser and engine-driven ROTREX Combination Pumps. Including a side outlet Gate Valve and "Multiflex" Atmospheric Exhaust Relief Valve.

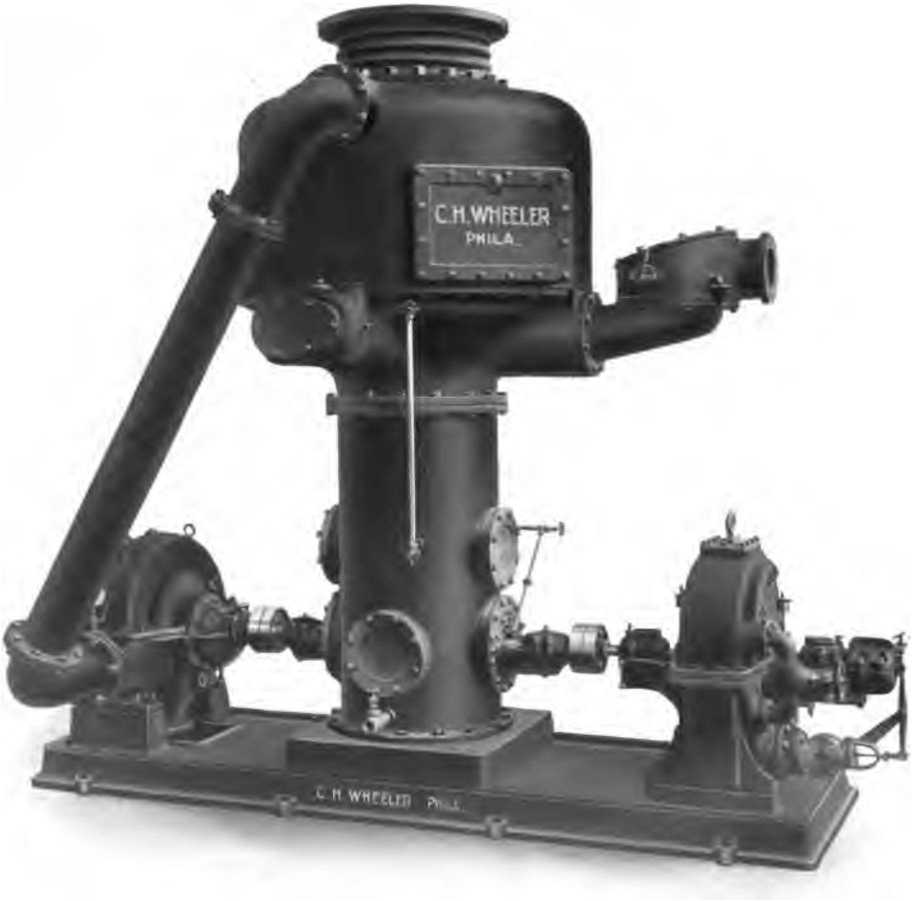


FIG. 5.

Low Level Jet Condenser with top exhaust inlet, having submerged Removal Pump and Thyssen Vacuum pump, both driven by one Turbine.

CHAPTER III

JET CONDENSERS

In this type of condenser the steam gives up its heat and condenses by direct contact with the cooling water. The mingled condensate and warm cooling water are removed either by a pump which discharges the water against the pressure of the atmosphere (as is the case in all "low level" jet condensers) or, if the condenser chamber be sufficiently elevated above the hot well tank, the water mixture is withdrawn through a vertical pipe (the tail pipe) the latter known as the Barometric Condenser.

A jet condenser may be arranged with either parallel flow of the cooling water and steam, or with opposite flow (so called "counter current" action). With the latter arrangement the steam and water flow against each other, *i.e.,* the entering steam encounters the warmest water and condenses as it rises, passing through successive curtains of water, obtained by suitably arranged overflow trays. Thus the temperature of the vapors is gradually reduced as they approach the top of the condenser, due to the proximity of the incoming injection water. Ultimately the mixture entering the suction pipe to the vacuum pump consists of air of relatively high density compared with that of the residual water vapors.

In a parallel flow condenser, the energy of the steam falling straight downwards with the water entrains the air along with it. This type is highly efficient when used in connection with an entrainment air pump, (see Chapter IX). The entrainment water in the air pump refrigerates the vapor mixture quite as effectually as the cold injection water of a counter current condenser, *i.e.,* the water vapor is condensed by the

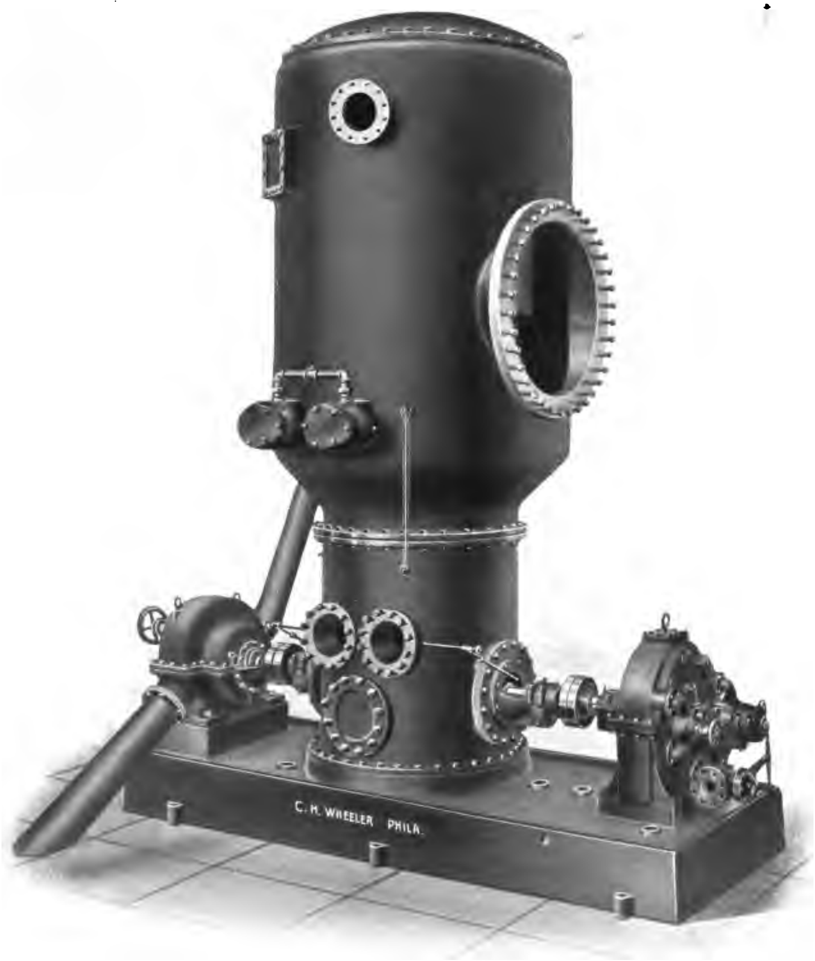


FIG. 6.
Side exhaust inlet Low Level Jet Condenser, with same pump combination as Fig. 5.

entrainment water and the pump has only to remove the air, so that a high vacuum is readily maintained.

Low Level Jet Condensers

It is possible with this type to raise the cooling water to the top of the condenser by the vacuum. The water removal pump draws from the base of the condenser under a head of about 5 feet thereby insuring constant priming; the remaining head of about 27 feet necessary to overcome the atmospheric pressure (assuming 2 inches absolute pressure in the condenser) is produced by the pump, and represents a fixed operating charge unavoidable with this type of condenser.

These condensers are frequently used on account of their low first cost. They are adapted for high vacuum under certain conditions, notably where the quality of the cooling water is not suitable for a surface condenser.

Ordinarily, however, the low level jet condenser is not the least expensive to operate, because of the power required to remove the cooling water from the condenser chamber against atmospheric pressure. To illustrate, let us consider the 10,000 KW. turbine referred to in Chapter II. Assuming that this turbine, delivering 150,000 pounds of steam hourly to the condenser, requires 35 pounds of cooling water per pound of steam, making a total of 5,400,000 pounds of cooling water per hour to be extracted against a net pressure equal to a 30-foot lift (corresponding to the vacuum head, plus friction). This gives 162,000,000 foot pounds per hour, or nearly 82 horsepower in work done by the removal pump; and dividing that by the efficiency of the pump itself will require about 125 horsepower delivered to the pump. Counting on an average cost of $40.00 per horsepower per year, we have an annual cost of $5,000.00 for the removal pump alone.

The circulating pump of a surface condenser for the same service, would operate against a friction head of probably not over 6 feet. Allowing for 15 per cent. more water circulated the power would cost about $1,150.00 per year. The difference of $3,850.00 annually would pay the difference in first cost between a jet and a surface condenser outfit for a

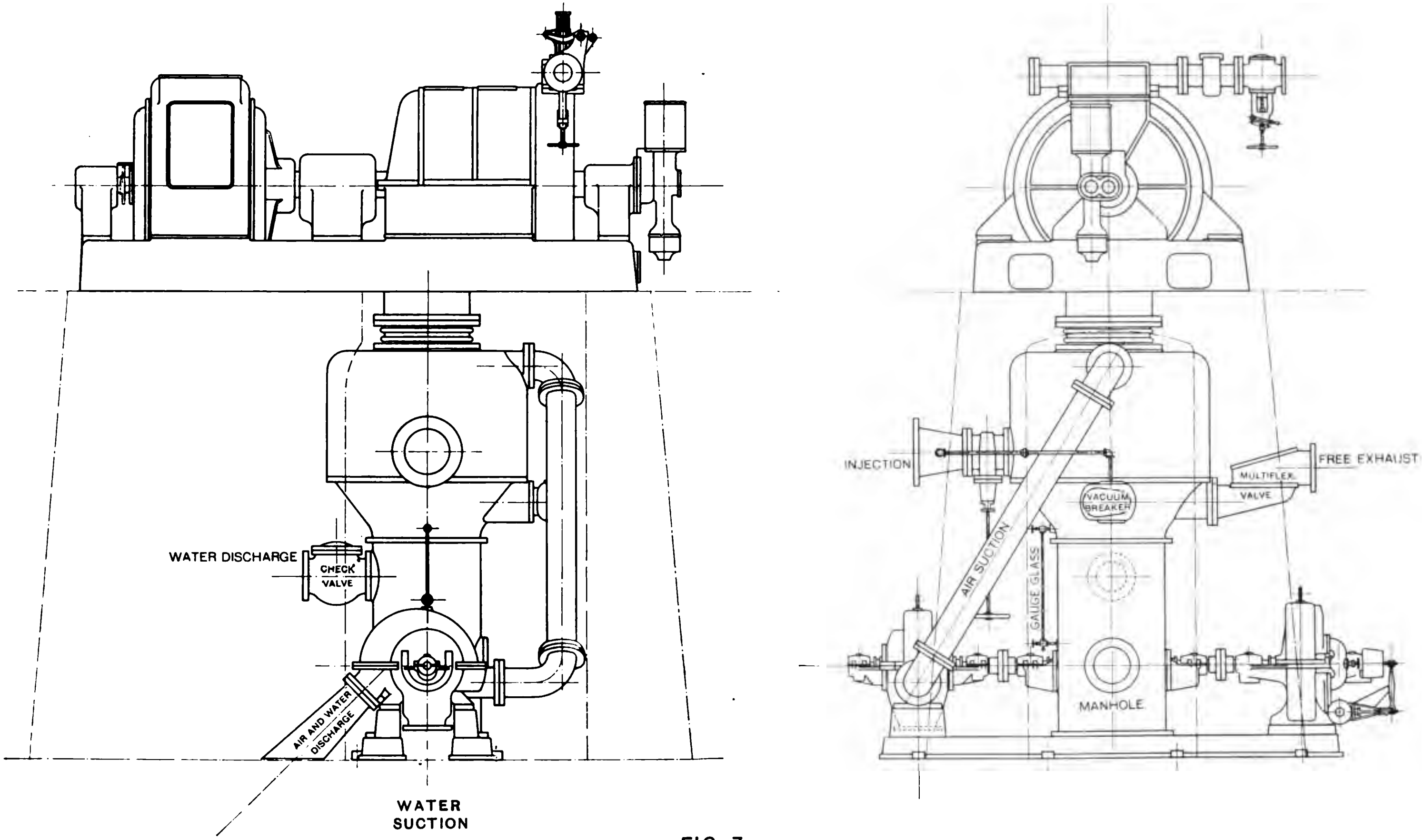


FIG. 7.

General arrangement of Turbine with top exhaust inlet Jet Condenser, Turbine driven Centrifugal Removal and THYSSEN *Air Pumps.*

10,000 KW. turbine in about three years, equivalent to a 33 per cent. dividend on the added investment. The above example illustrates the economy of using a surface condenser in all instances where local conditions favor its installation.

C. H. Wheeler Low Level Jet Condensers are built in two general types, one with side exhaust inlet and the other with inlet on the top of the condenser chamber. The former is designed to operate on the counter current principle as shown in Fig. 11, wherein the flow of the steam and water is clearly visible. The cooling water falls over a series of perforated troughs, forming thin water curtains which the steam must pass through while ascending and before reaching the air space at the top. In this manner the air is cooled and the water vapor condensed before passing to the air pump.

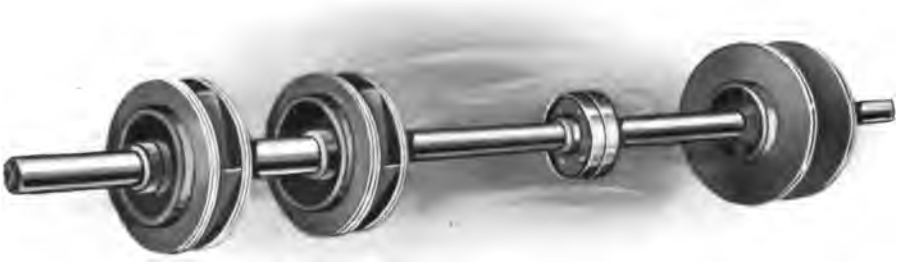


FIG. 8

The only moving part in a C. H. WHEELER-THYSSEN Jet Condenser.

The most desirable arrangement of a jet condenser is illustrated by Fig. 7, showing a condenser located directly underneath the turbine. This permits locating the exhaust inlet on top of the condenser chamber. In this design the cooling water overflows the annular weir forming the top of the cone, the wetted surface of which condenses the steam. The steam passes through this cone at high velocity, entraining with it the air, so that the pressure in the lower half of the

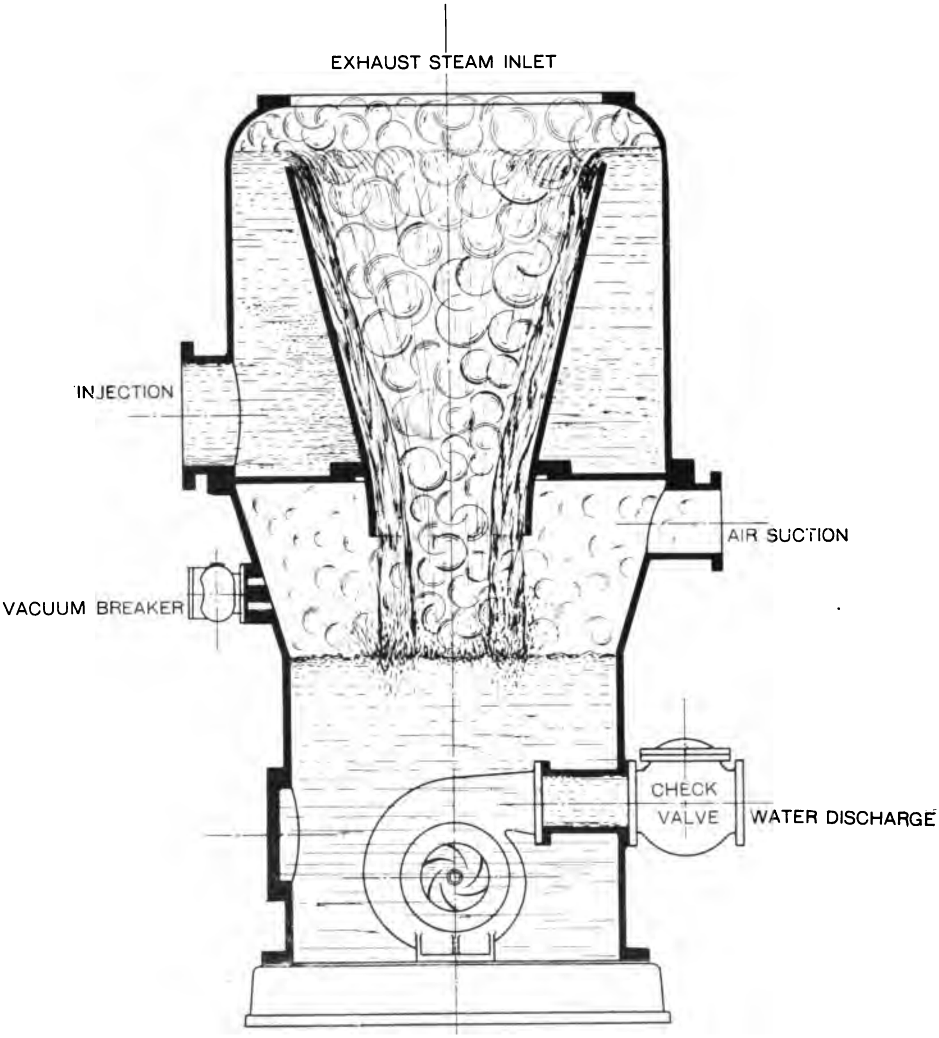


FIG. 9.

Top Exhaust Inlet Parallel Flow Jet Condenser with submerged Removal Pumps.

condenser may be slightly greater than at the inlet, notwithstanding the condensation. With this type of condenser the temperature than in the counter current type; and the relative vapor mixture entering the air pump suction pipe has a higher tension of the water vapor going to the pump is considerably greater. However, as these condensers are used in connection with Thyssen Entrainment pumps only, the higher vapor tension is not objectionable, inasmuch as the entrainment pump acts as an auxiliary condenser. The condenser itself is simpler than the counter current type, while the vacuum is equal to that produced in the latter.

Whenever a vacuum pump of the displacement type is used with a jet condenser, the counter current design shown in Fig. 10 is recommended, for the reasons already set forth; permitting the use of a pump of smaller capacity than would be possible with a condenser of the parallel flow type.

In all jet condensers the water removal pump is submerged several feet, to insure priming at all time and reduce the entering head to a minimum; the height of the water level is controlled by a gauge glass connected to the condenser chamber. The vacuum and removal pumps are preferably operated by one motor, turbine or engine.

Automatic Vacuum Breaker

To protect the main engine or turbine from flooding, every jet condenser is provided with an automatic vacuum breaker, in case the water removal pump should fail. At the usual rate of flow a jet condenser would be entirely filled with water in a few minutes should the removal pump stop, unless provision is made to break the vacuum and thereby stop the suction of the incoming water. The automatic vacuum breaker fulfills this purpose by opening an air admission valve controlled by a float and lever, thereby preventing any abnormal rise of the water level in the condenser chamber.

In some condensers the valve simply admits air into the body of the condenser. The valve being necessarily small

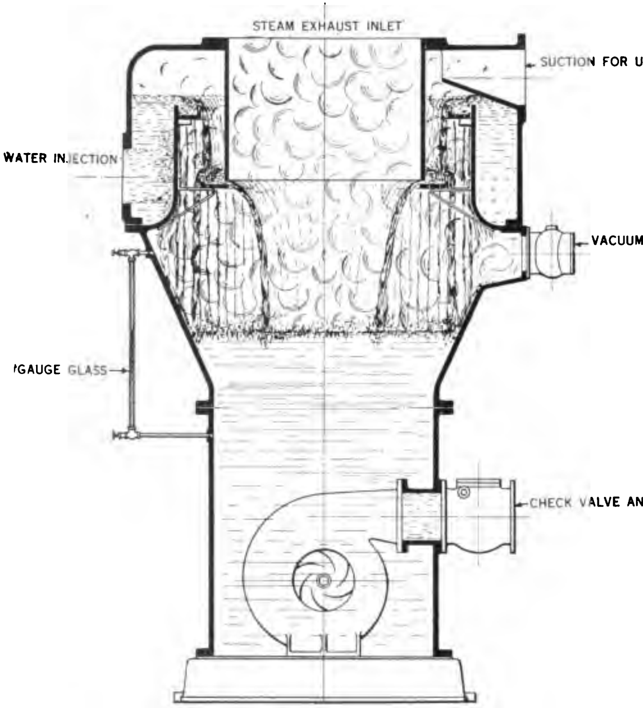

STEAM EXHAUST INLET
SUCTION FOR UNCONDENSABLE VAPORS
WATER INJECTION
VACUUM BREAKER
GAUGE GLASS
CHECK VALVE AND WATER DISCHARGE

FIG. 10.

Top Exhaust Inlet Counter-Current Jet Condenser, with submerged Removal Pump.

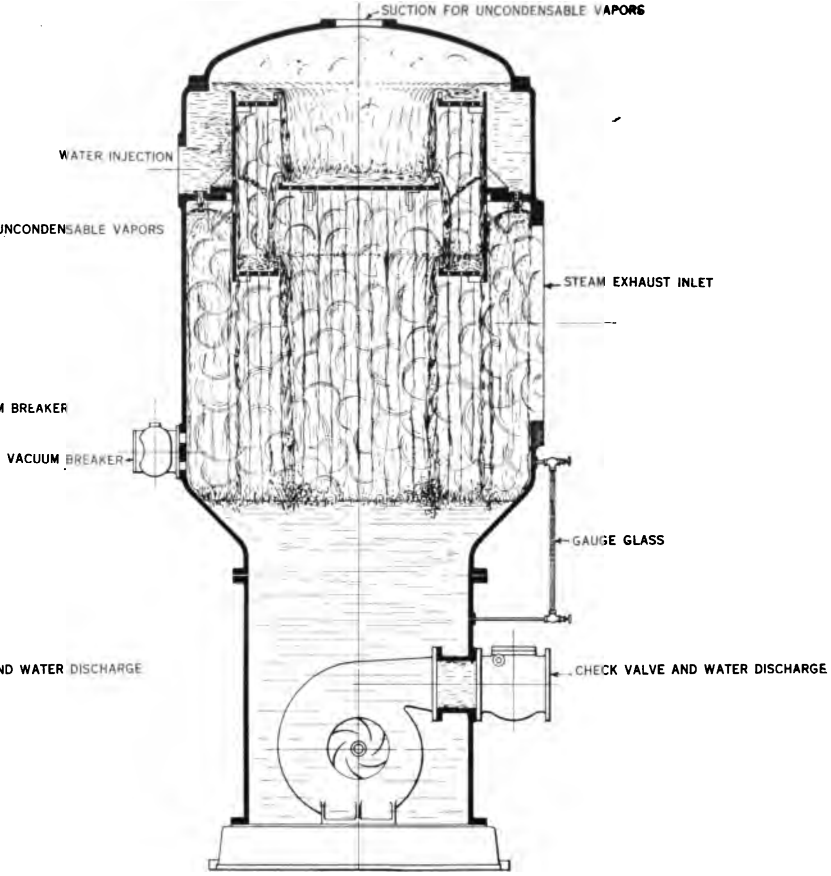

SUCTION FOR UNCONDENSABLE VAPORS
WATER INJECTION
STEAM EXHAUST INLET
VACUUM BREAKER
GAUGE GLASS
CHECK VALVE AND WATER DISCHARGE

FIG. 11.

Counter-Current Vertical Low Level Jet Condenser, with side exhaust inlet and submerged Centrifugal Removal Pump.

requires too much time to admit sufficient air to prevent flooding the condenser and the engine or turbine is endangered before the water supply is cut off.

This feature, which may develop serious consequences, is avoided in C. H. Wheeler Jet Condensers by the arrangement shown in Fig. 7. Here the float valve is of the usual type, but the air which it admits (instead of going to the interior of the condenser) is carried through a small pipe into the water suction pipe back of the injection valve. It is evident that the smallest quantity of air admitted at this point, will expand under the influence of the vacuum in the suction pipe sufficiently to break the water column instantly, and thereby stop the supply to the condenser. This simple device has been thoroughly tested, proving the impossibility of raising the water above the level of the float before the water suction was broken. The value of this arrangement in protecting a turbine or engine from damage cannot be over estimated.

Condensers of smaller sizes are mounted on a common base with direct acting air and water removal pumps. See Figs. 12 and 13. Where the cooling water is not discharged under a head the air and water may be handled in one pump, as in Fig. 12. When, however, the water has to be pumped against a head it is necessary to remove the air and water in separate cylinders. This is done as shown in Fig. 13, the water pump receiving the mixture of condensate and cooling water from the base of the condenser and the air cylinder taking the non-condensable vapors together with a small amount of cooling or sealing water through the pipe shown above the pump, the steam cylinder being placed between the two pump cylinders.

For very large units with capacities of 7,500 KW. and over, C. H. Wheeler Jet Condensers are provided with horizontal cylindrical cast iron shells, the cooling water distribution consisting of a special nozzle and weir arrangement.

Installations of this size should be considered individually and designed with due consideration to the particular conditions of the power plant.

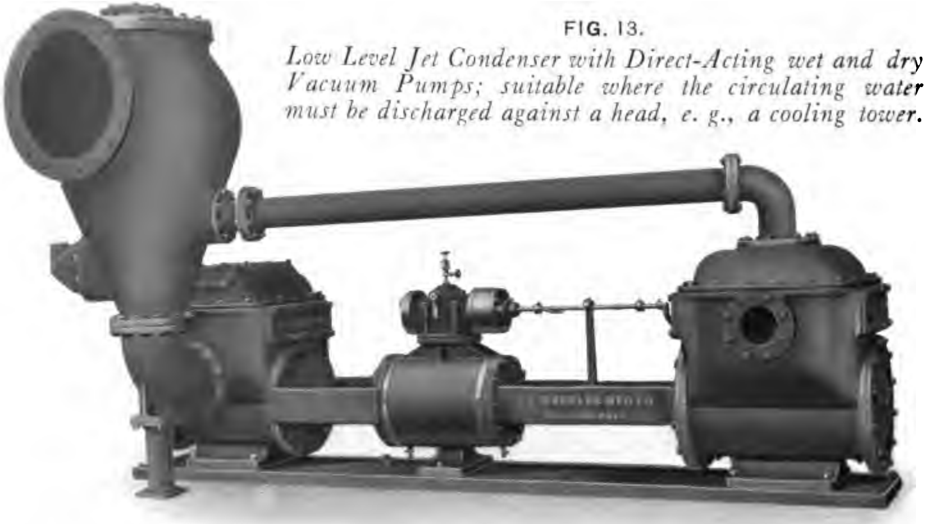


FIG. 13.

Low Level Jet Condenser with Direct-Acting wet and ***dry*** *Vacuum Pumps; suitable where the circulating* ***water*** *must be discharged against a head, e. g.,* ***a cooling tower.***

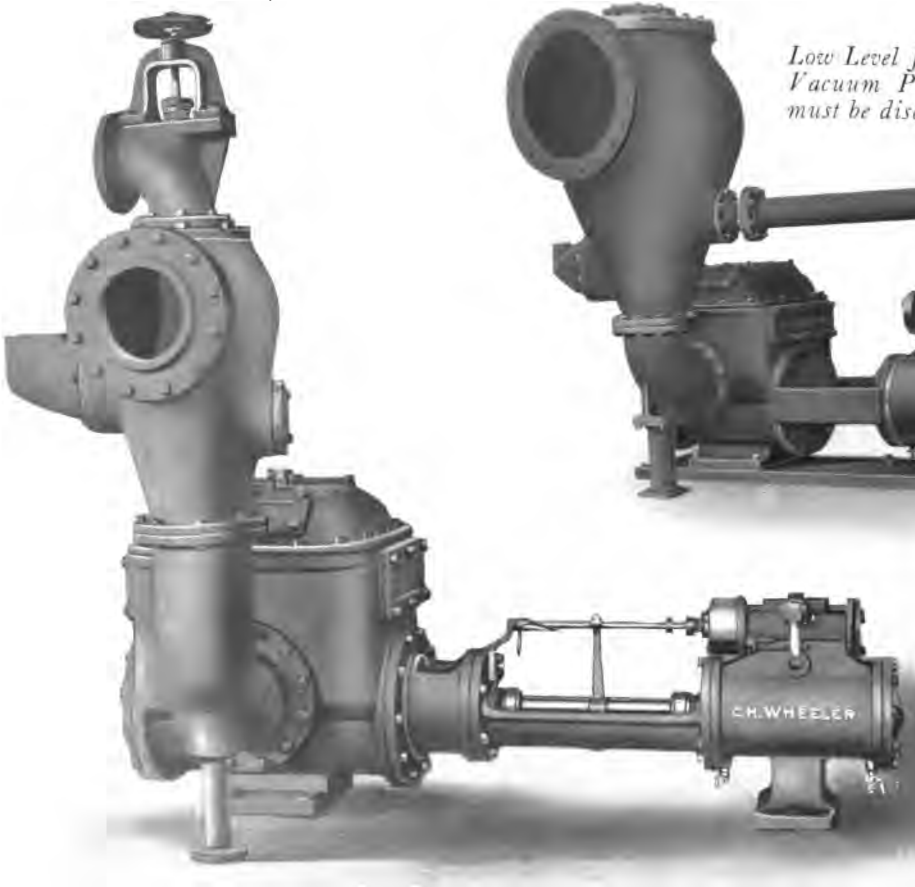


FIG. 12.

Jet Condenser with single Direct-Acting Air Pump. A simple ***and*** *low priced outfit for use with* ***re-*** *ciprocating engines.*

Barometric Condensers

The chamber of this type is designed along the same lines as the Low Level Jet Condenser already described; with the addition of the exhaust and tail pipes, the latter forming a kind of water barometer, with a height of about 34 feet. In the

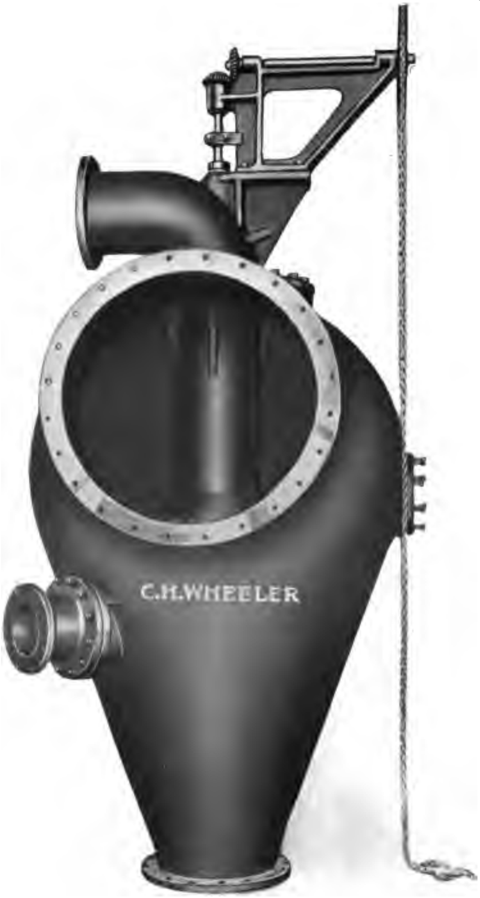


FIG. 14.

Barometric Condenser Head with adjustable injection arrangement.

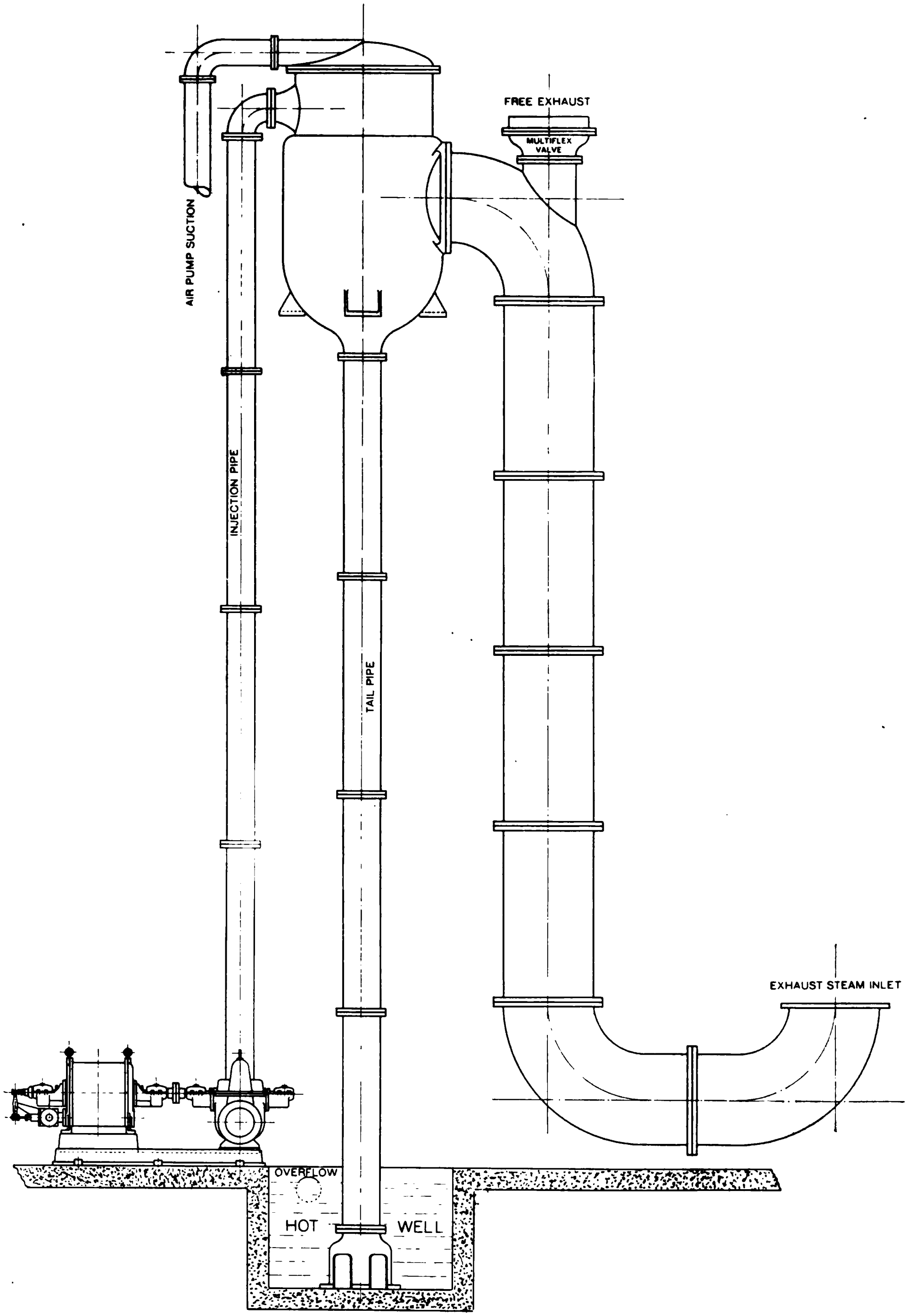


FIG. 15.

General arrangement of Counter-Current Barometric Condenser and Turbine-driven Injection Pump. The air pump is not shown, but any type may be used.

larger sizes the counter current principle is applied as shown in Figs. 10 and 11. For smaller units the internal arrangement is simplified to suit the reduced space.

To avoid the shortcomings inherent to the ejector throat sometimes inserted between the condenser chamber and the tail pipe, C. H. Wheeler Barometric Condensers dispense with this device. Experience proves that these throats are not as efficient in removing the non-condensable vapors as a good air pump; and that they are very sensitive to changes in load and temperature of the injection water. A certain percentage of air is entrained with the water into the tail pipe (even when no special throat is provided) and it is safer and more economical to remove the rest by a vacuum pump than by pumping through the condenser an excess quantity (50 to 100 per cent.) of water to remove the residual air without a pump. For this reason, as well as to avoid failure of the air entrainment at light loads, all C. H. Wheeler Barometric Condensers operate with an air pump.

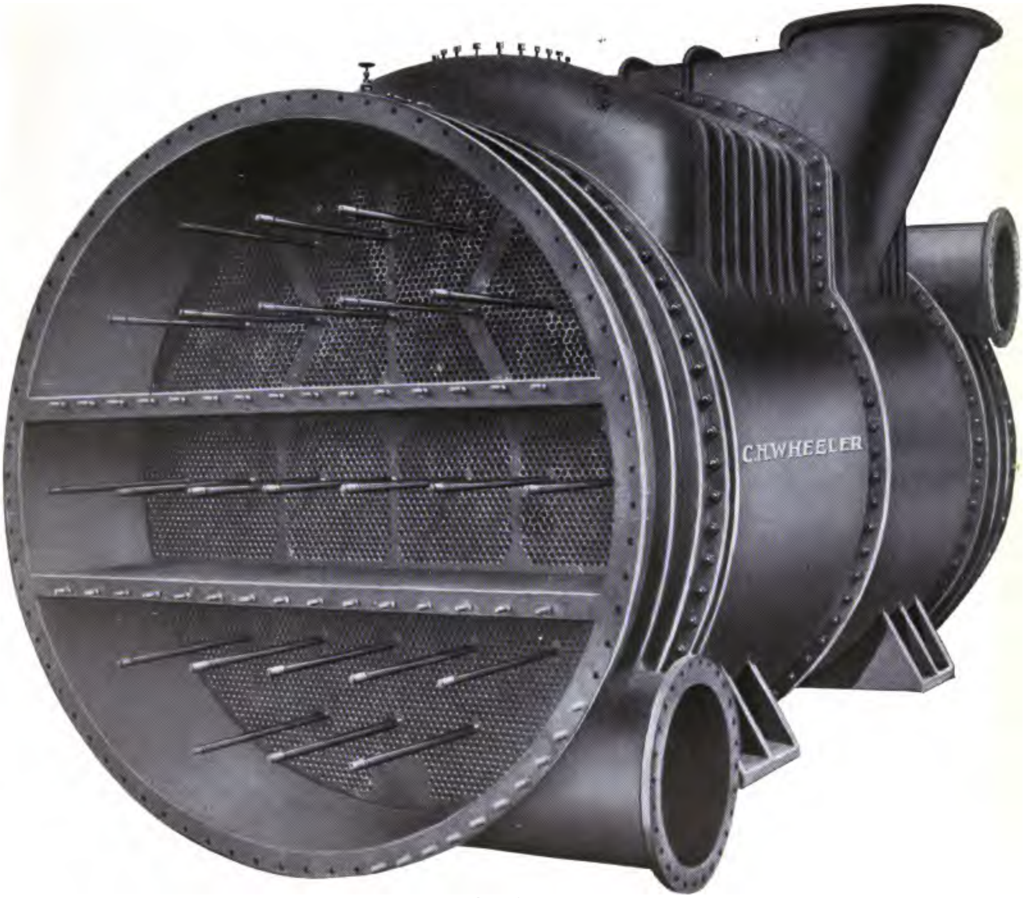


FIG. 16.

Surface Condenser for 7500 KW. Turbine. The end cover is removed, showing stay bolts, steam lanes, etc. This condenser is of three-pass design; and specially reinforced to sustain the pumping head due to a water cooling tower.

CHAPTER IV

SURFACE CONDENSERS

In Chapter III we mentioned the advantage of the surface condenser over the jet type, due to the feasibility of combining high vacuum with low operating cost, resulting from the smaller pumping head required to circulate the cooling water.

In addition the surface system permits the use of impure or salt cooling water.

By arranging the cooling water inlet and outlet so that the flow may be reversed at will, even muddy water can be used without the necessity of frequent cleaning; this being accomplished by occasionally reversing the flow, flushing the sediment and leaving the tubes and water chamber clean.

A surface condenser affords the only reliable means of measuring the actual steam consumption of a steam turbine or engine. This is obvious because the exhaust steam from the main unit remains entirely separate from the cooling water; hence it is a simple matter to measure the condensate in the hot well and avoid the possibility of an error by calculating the steam consumption from the boiler feed.

The efficiency of the surface condenser, determined by the quantity of steam it will condense per hour per square foot of cooling surface, when using a given quantity of cooling water, depends principally upon the following factors:

1—Velocity of the water in the tubes.

2—Terminal difference in temperature between the water and steam.

3—Efficient steam distribution over the cooling surface.

4—Absence of air in the condenser.

5—Freedom of the tubes from flooding by condensate.

6—Condition of the tube surface.

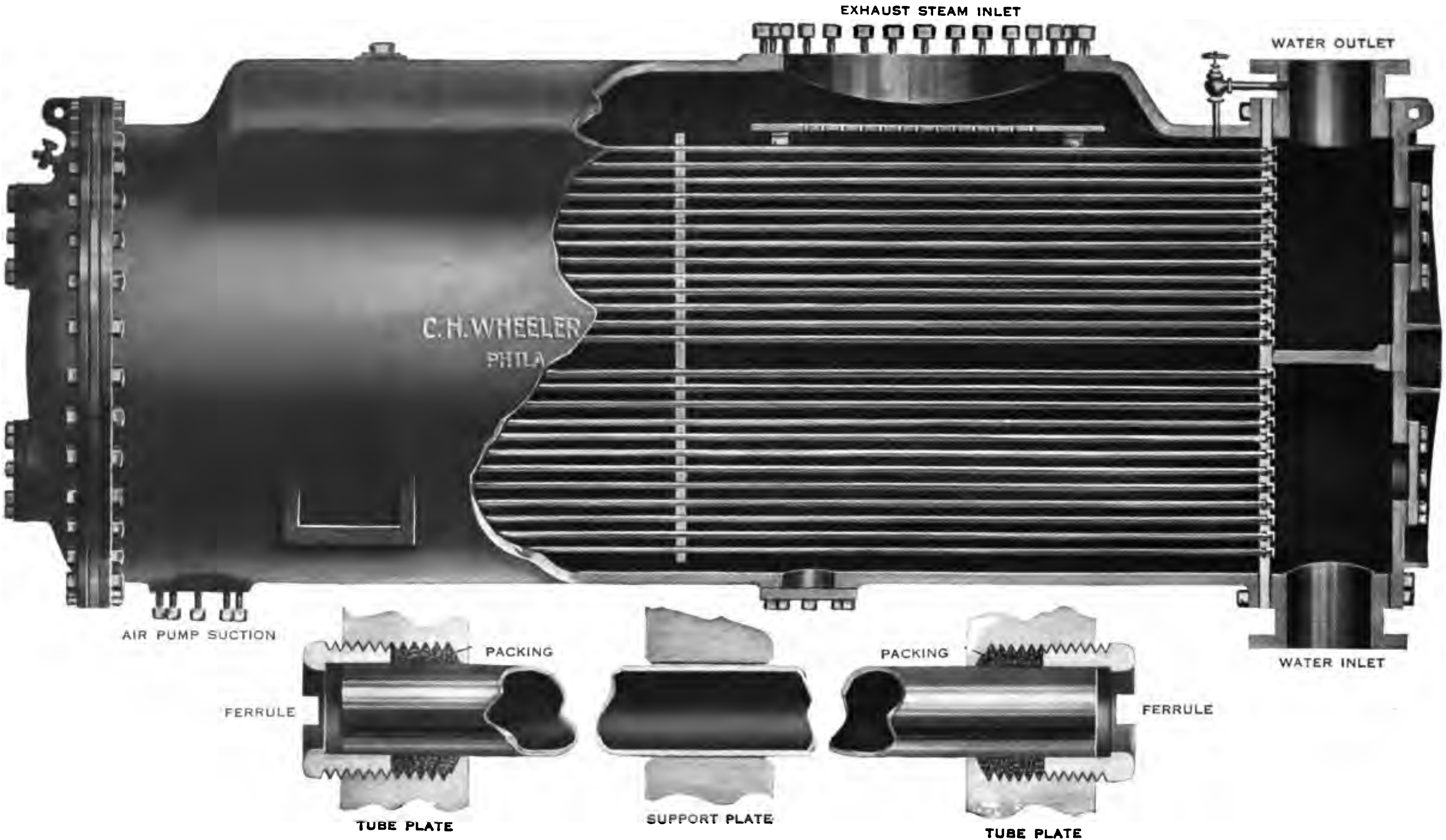


FIG. 17.

Section of standard two-pass Surface Condenser, having top exhaust inlet, and arranged for operation on the wet system.

First.—The velocity of flow through the tubes has much to do with the heat transfer between steam and water. This is probably due to the fact that a rapid stream churns itself, so that the center (*i.e.,* the core) of the stream is not allowed to remain cold while the portions next to the tube walls are heated. However that may be, the fact is well established that, the higher the rate of flow the greater the coefficient of heat transmission.

On the other hand, the head required to force the water through a tube of given diameter and length increases as the square of the velocity. The usual practice is to compromise on a condenser having a friction head of from 5 to 15 feet, depending upon the duty to be performed. To secure the desired velocity of water flow, the tubes are divided into two or more groups, through which the water passes in series. To accomplish this, the water chambers at the ends of the condenser are divided by bridges as shown in Figs. 16, 17, etc.

Second.—The relation between the quantities of steam and cooling water and the cooling surface is as follows: with a given quantity of steam and for a constant vacuum, an increase in the amount of cooling water increases the terminal difference or "temperature head" between the steam and the circulating water, reducing at the same time the condensing or cooling surface necessary. On the other hand, reducing the quantity of cooling water, reduces the "temperature head," but rapidly increases the cooling surface required. A study of the curve in Fig. 3 will make this clear. The relation of the terminal difference in temperatures and the corresponding cooling surface is expressed by a hyperbolic curve. It is obvious from this curve that the cooling surface increases very rapidly as the cooling water approaches the temperature of the steam. Based on the above a terminal difference not exceeding 8 to 15 degrees Fahrenheit has been adopted as the most economical; and the best practice tends toward reducing the pumping cost rather than cut down the size of the condenser.

Third.—the steam should take the shortest path through the condenser with the least baffling possible. The spacing of

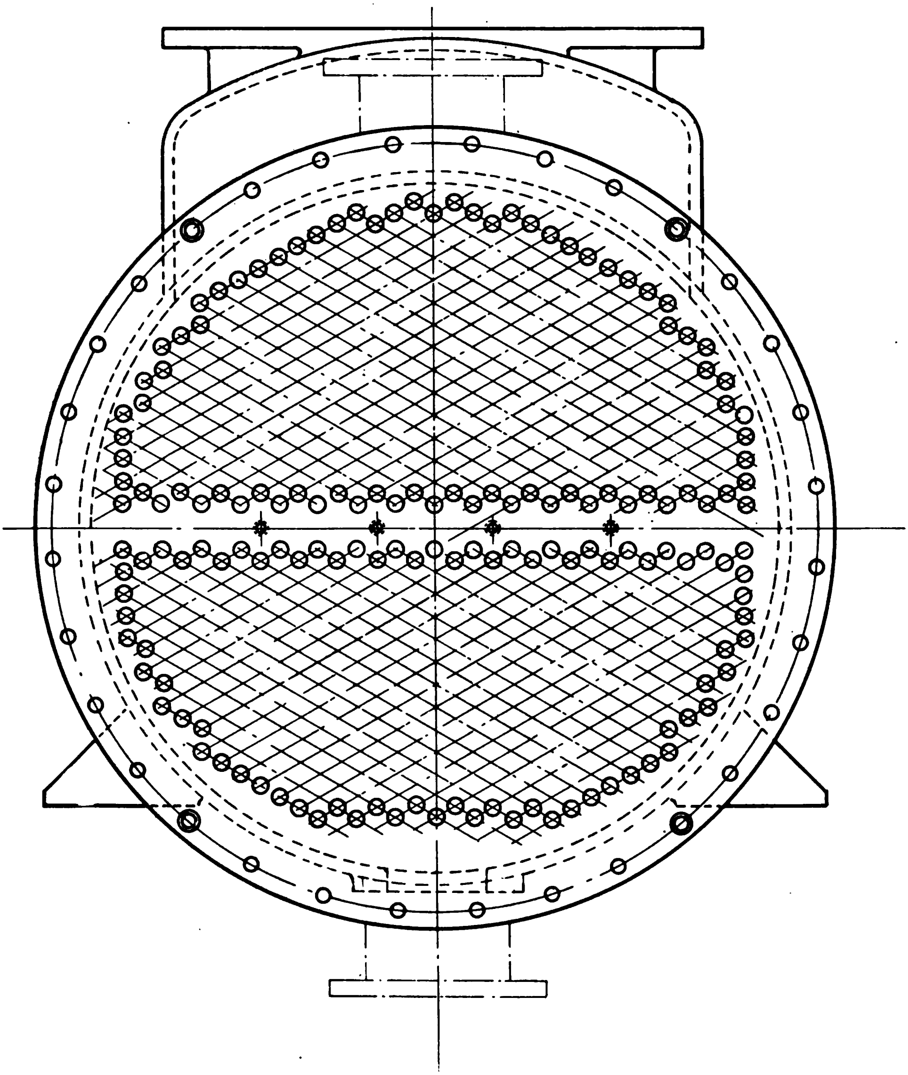


FIG. 18.

Tube Sheet layout for standard two-pass Surface Condenser shown in Fig. 17, having top exhaust inlet and operating on the wet system.

the tubes has a very important bearing on the efficiency of the cooling surface. The old conception which regarded a surface condenser merely as "a box packed full of tubes" resulted in the construction of condensers with tubes so closely spaced as to seriously impede the flow of steam. In a properly designed condenser the pressure drop from the exhaust steam inlet to the air pump connection should be but a fraction of an inch; where, however, the spacing of the tubes is inadequate it may be considerably over one inch. In all but the smallest sizes, ample space should be provided for steam distribution near the inlet, where most of the steam is condensed. In the lower tube banks (*i.e.,* near the air pump suction) the duty of the cooling surface is to refrigerate the air and condense the residual water vapor.

Fig. 19 illustrates the arrangement of tubes in C. H. WHEELER condensers; and in all but the smallest sizes the upper tube rows are spaced on wider centers than the lower tubes, or, sometimes are grouped to form steam lanes, thereby giving the steam access to the middle and lower tubes.

Fourth.—Absence of air. This is important in view of the fact that even small quantities of air entering with the exhaust steam through leakage impair the vacuum much more than is generally supposed. The air interferes with the heat exchange between steam and water; *i.e.,* with the cooling effect of the tube surface; hence any indication that the vacuum is lower than it should be necessitates prompt search for air leaks.

Fifth.—Flooding of tubes by the condensate. Surface condensers are often provided with socalled "drain plates" as shown in Fig. 20. The object is to intercept the condensed steam flowing over the upper tubes and deflect or turn it to the sides and bottom of the condenser chamber, thus keeping the tubes dry, relatively speaking. Flooding the tubes is detrimental, because water is a poor conductor of heat. It is desirable to collect the condensate by means of drain plates, suitably distributed between the tube banks, to insure its reaching the hot well with the least possible loss in tem-

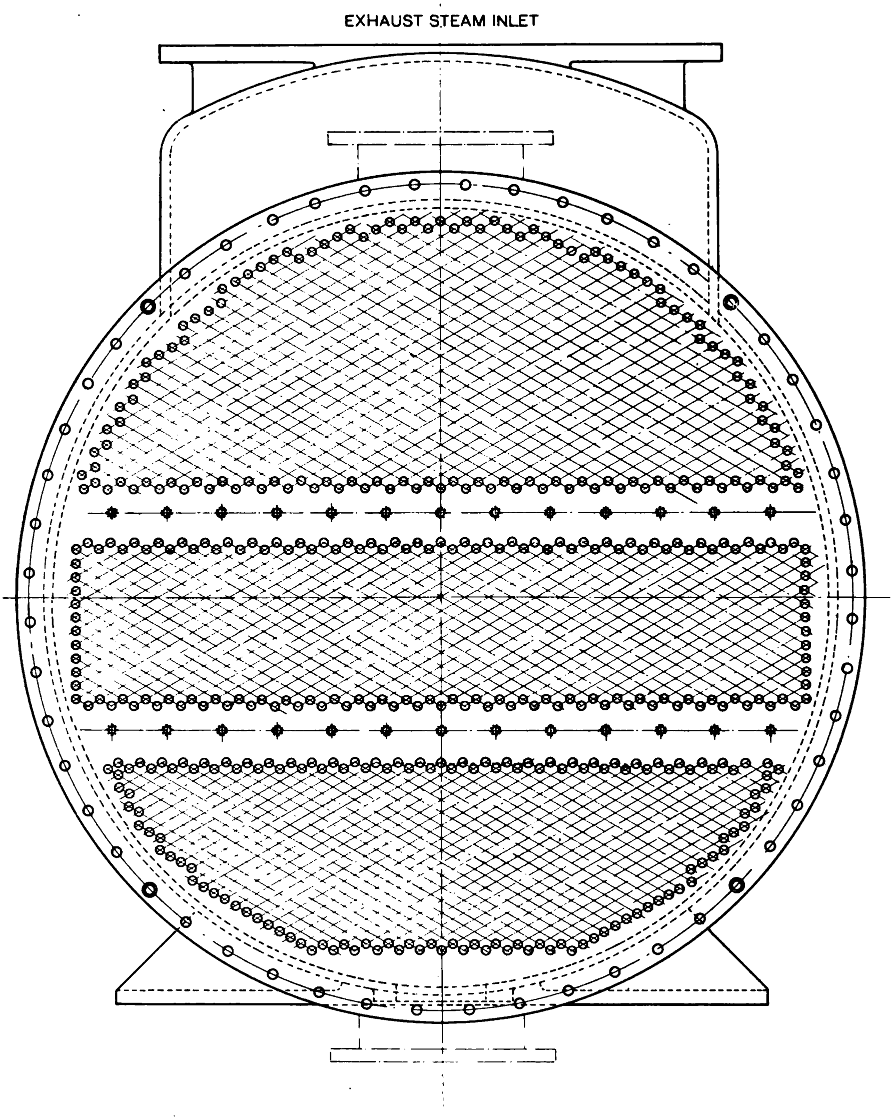


FIG. 19.

Tube sheet layout for a three-pass top exhaust inlet surface Condenser, having differential tube spacing, and arranged for wet system operation.

perature; bearing in mind that the condensate must be reheated before again entering the boiler.

Sixth.—Condition of the tube surface. Assuming that the condenser is correctly proportioned for its work, the cooling surface is determined by the factors mentioned and by the degree of cleanness of the tubes. Under exceptional conditions clean tubes will transmit 1,000 B. T. U.'s per square foot per hour for each degree Fahrenheit of temperature difference between the water and steam. A condenser rated on such a basis, however, would undoubtedly fall short of maintaining the desired vacuum under usual operating conditions. The slightest deposit on the tubes will reduce the condensing capacity; and the influence of this and other causes on the heat transfer must be considered when determining the proper size of the condenser.

Taking into account all these conditions, the C. H. WHEELER MANUFACTURING COMPANY use a coefficient of heat transmission varying with individual cases, ranging from 300 to 400 B. T. U.'s per square foot per hour for each degree Fahrenheit of temperature difference.

C. H. Wheeler Surface Condensers are arranged for either "wet" or "wet and dry" vacuum operation. The wet vacuum system is used to advantage for plants of moderate size, as it eliminates a separate condensate pump. The outlet to the air pump is located so as to refrigerate the condensate over the lower tubes, which, as they receive the entering water, are also the coldest. Another object of cooling the condensate is to reduce the vapor tension as much as possible before it enters the air pump.

When the condenser is arranged for wet and dry operation, no tubes are submerged, as the air pump does not remove the condensate. Occasionally a condenser is built to operate on the wet and dry system, but with a provision for the automatic submerging of the lowest tubes in case the condensate removal pump (hot well pump) is shut down, in which event the work of the latter is performed by the air pump.

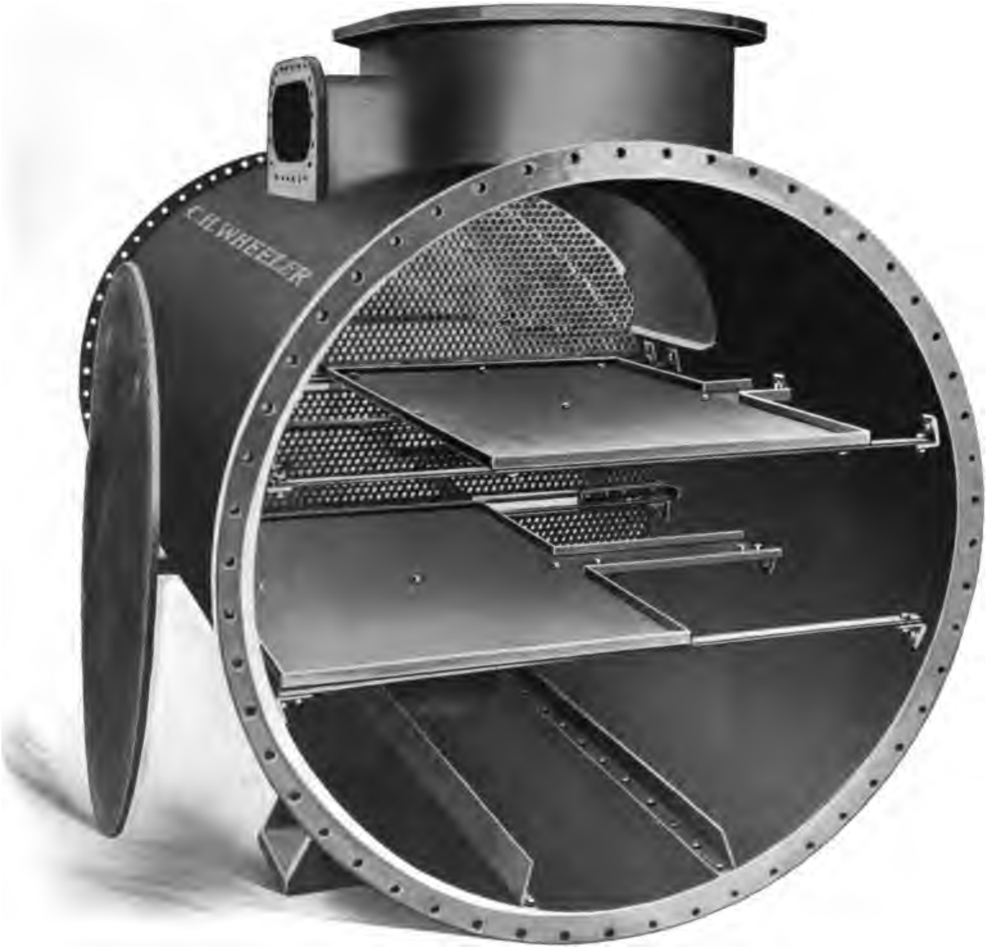


FIG. 20.

Interior of large Surface Condenser with top exhaust inlet; drain trays arranged for operation on the wet and dry system.

A condenser with side exhaust inlet is shown in Fig. 21. To guide the flow of the steam and collect the condensate, a deflector is provided along the base of the dome.

The partitions in the water ends of medium and large size condensers, dividing the flow of the circulating water in two or more passes through the tubes, are provided with stay-bolts through the end covers to strengthen the tube plates against the atmospheric and water pressure. These are seen in Figs. 19, 22, etc. Very large condensers require additional stay-bolts as shown in Fig. 16. This illustration also shows the spacing of the upper and middle sets of tubes to

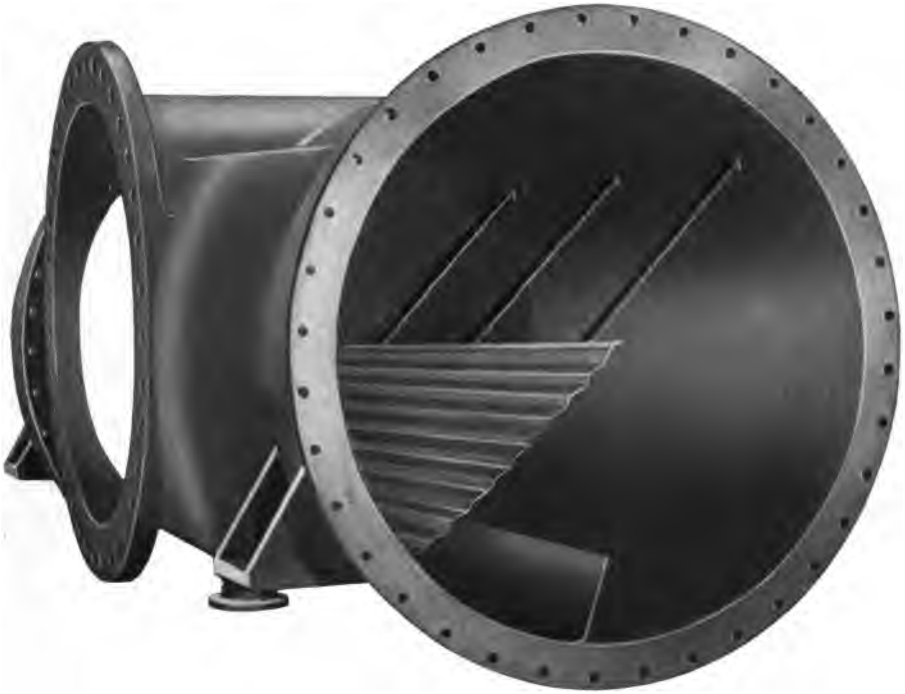
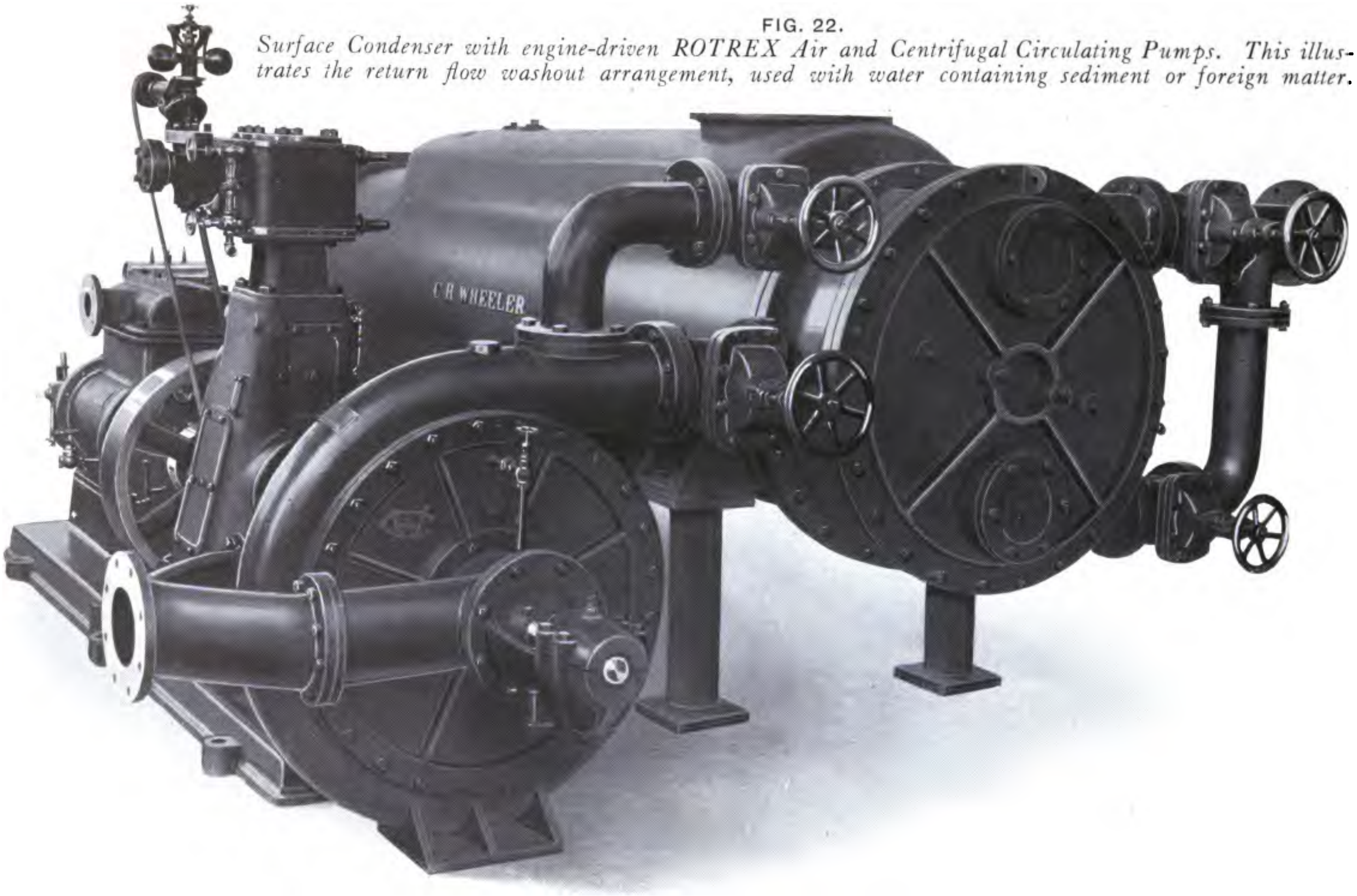


FIG. 21.

Interior of Surface Condenser with side exhaust inlet, showing drain deflector plate. This condenser is intended for the wet system.

FIG. 22.

Surface Condenser with engine-driven ROTREX Air and Centrifugal Circulating Pumps. This illustrates the return flow washout arrangement, used with water containing sediment or foreign matter.



provide lanes, whereby a portion of the steam is given direct access to the inner tubes. These lanes are equivalent to the wider spacing of the upper tubes mentioned on page 39, and illustrated in Fig. 19.

Sometimes the relative location of turbine and condenser make it necessary for the exhaust steam to enter at the bottom. In that case the cooling water enters at the top and discharges at the bottom, in order to secure counter current flow. This arrangement is shown in Fig. 23.

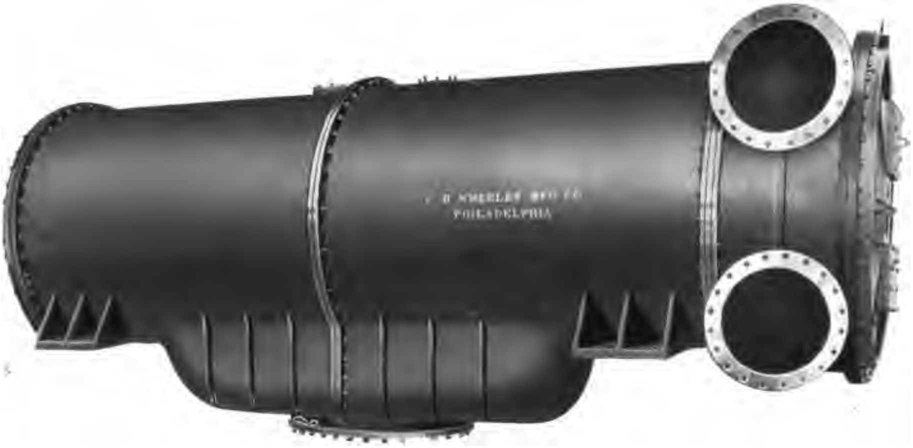


FIG. 23.

Two-pass Surface Condenser with bottom exhaust inlet operating on wet and dry system. The cooling water enters at the top and leaves at the bottom, providing a counter-current action.

In Fig. 30 the steam enters at the bottom, but instead of passing directly into the condenser, it flows through a ring passage around the shell to a top inlet.

An interesting example of adaptation to special conditions is the large surface condenser shown in Fig. 32. This condenser, owing to space limitations, had to be placed vertically. It also uses muddy water. The water enters the lower chamber, rises vertically through one bank and descends through the other to an outlet at the same level as the inlet. The height from the top of the condenser to the outlet of the discharge pipe being less than 30 feet, the water circulation in the condenser takes place under a sealed syphon, the circulating pump having to overcome only the friction of the tubes and piping. The water chamber at the top of the condenser is higher than usual; and has a gauge glass, the purpose of which is mentioned presently. The inlets and outlets are in duplicate and cross connected, so that by opening and closing suitable valves, the direction of flow can be reversed periodically for the purpose of flushing accumulated sediment. In case the tubes should require cleaning this can be done without interrupting the operation of the condenser, by breaking the vacuum at the top head through an air valve provided for that purpose, dropping the water in the top chamber about half-way down the gauge glass, and lifting off the cover, thus exposing the top ends of all the tubes. This makes it necessary only to speed up the circulating pump to overcome the added head, due to the temporary breaking of the syphon action.

For waterworks and pumping stations the special form of condenser shown in Figs. 24 and 25 is used. In these installations all the water going to the pumping engine is passed through the condenser, so that the question of economy in the use of water does not arise; the only consideration is to provide sufficient tube surface and minimize the resistance to the flow of the water. In these condensers the water is made to flow around the tubes instead of through them. The tubes are spaced on wider centers than usual. The end covers of all C. H. Wheeler surface condensers are removable without disturbing the piping. This is shown in the illustrations.

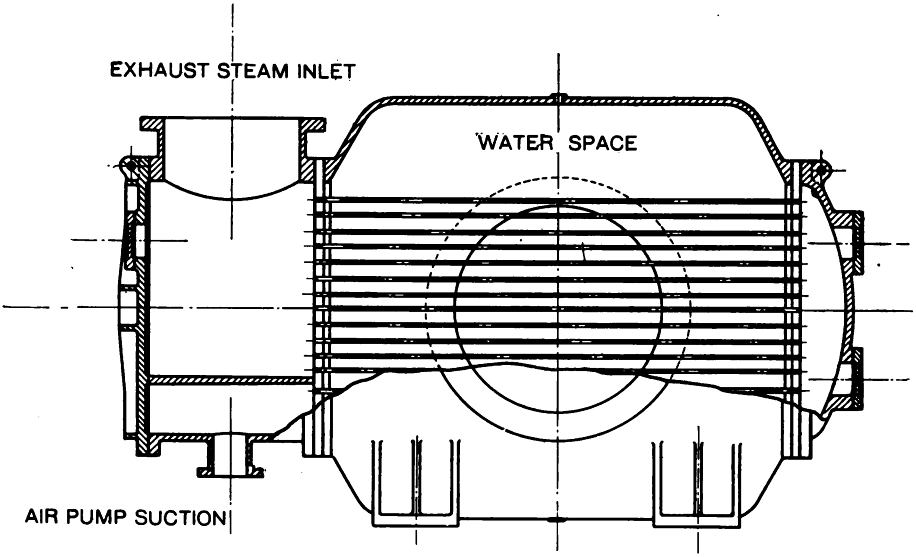


FIG. 24.

Section of Standard Water Works Condenser. Water passes through the shell and the steam inside the tubes.

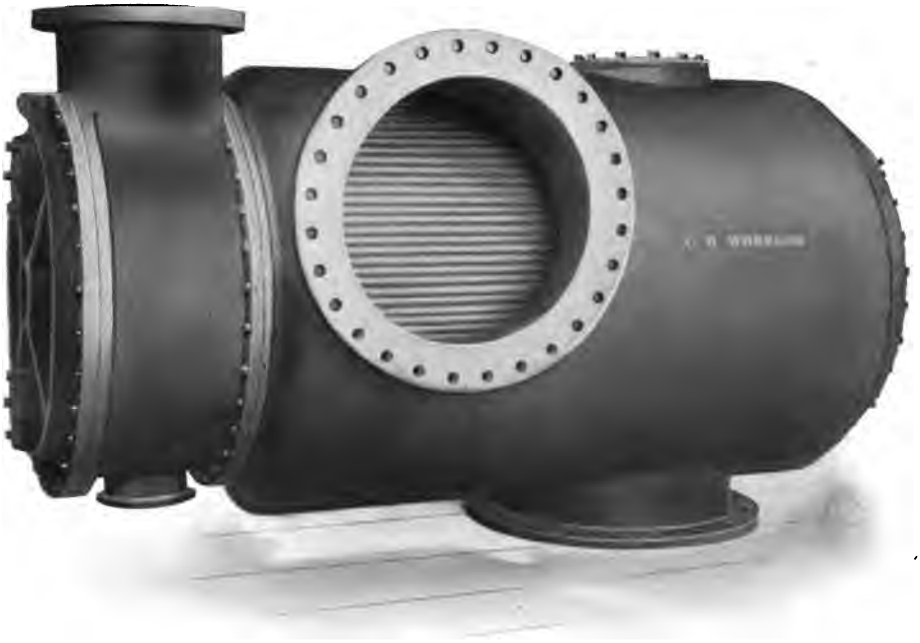


FIG. 25.

Outside view of Standard Water Works Condenser.

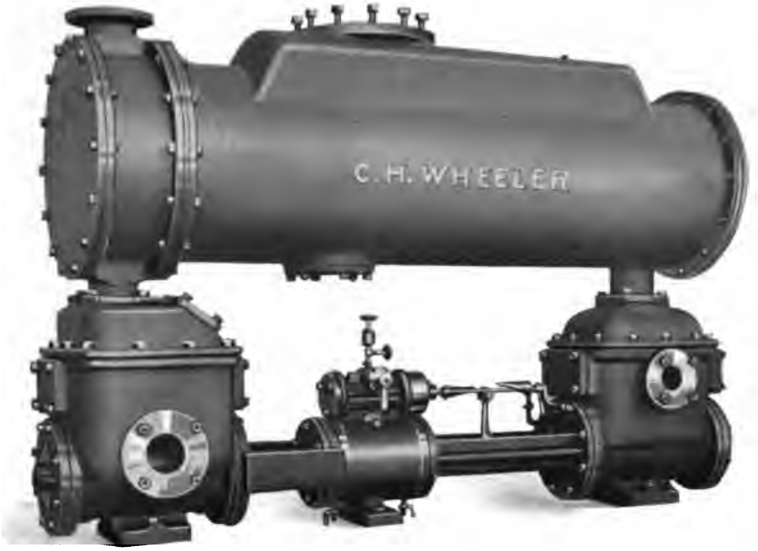


FIG. 26.
Surface Condenser with direct-acting Circulating and Suction Valveless Air Pumps.

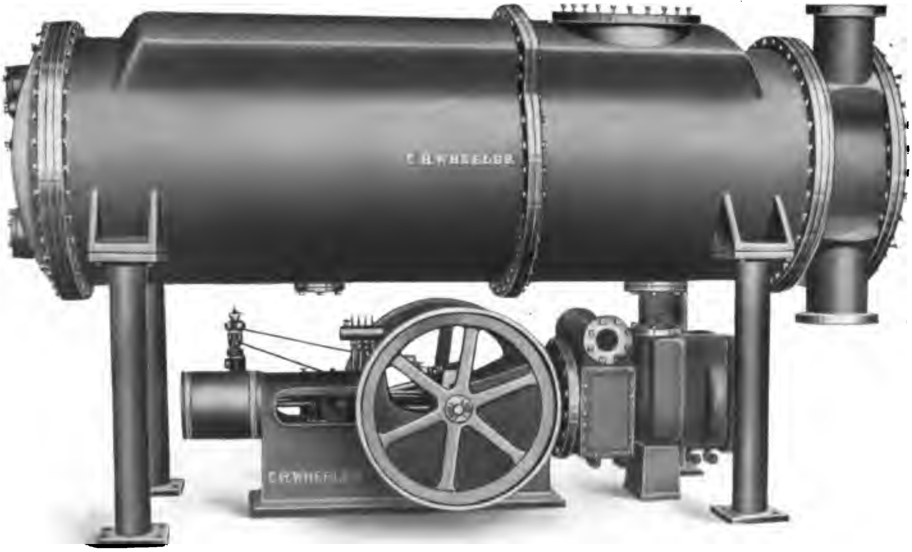


FIG. 27.
Surface Condenser mounted over Mullan Air Pump.

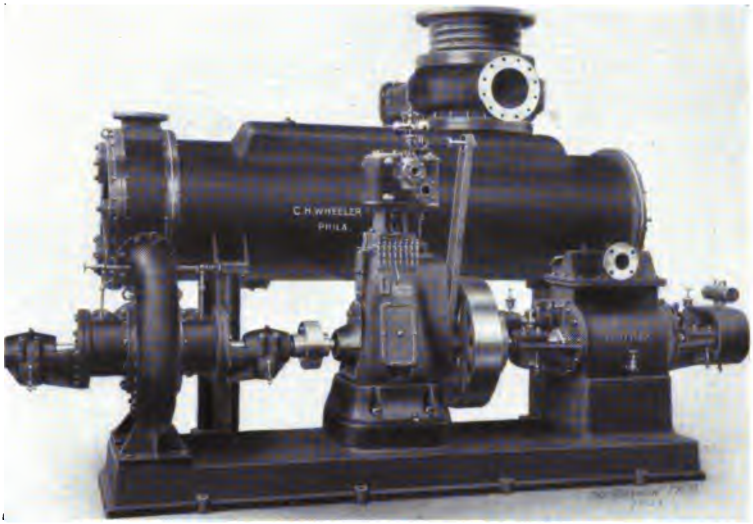


FIG. 28.

Surface Condenser for unit of moderate size, having engine-driven direct-connected ROTREX Vacuum Pump and Centrifugal Circulating Pump. Expansion Joint and side outlet Gate Valve are also shown.

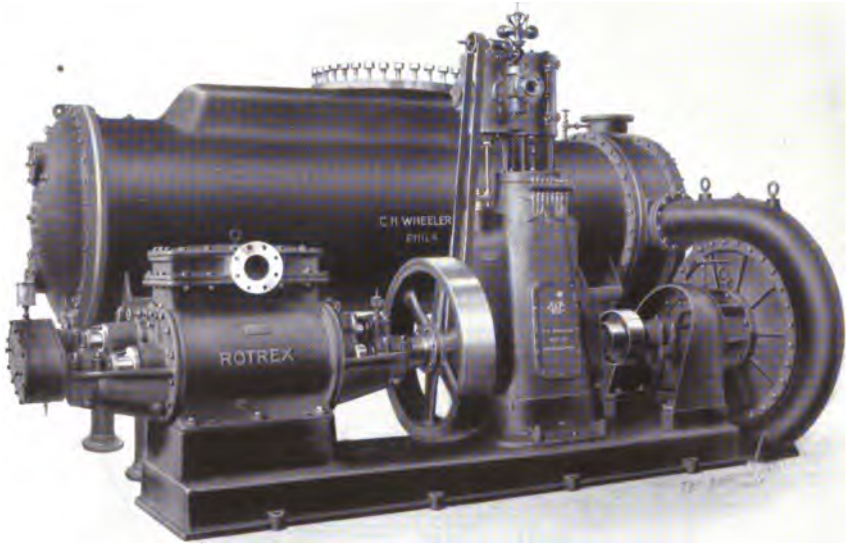
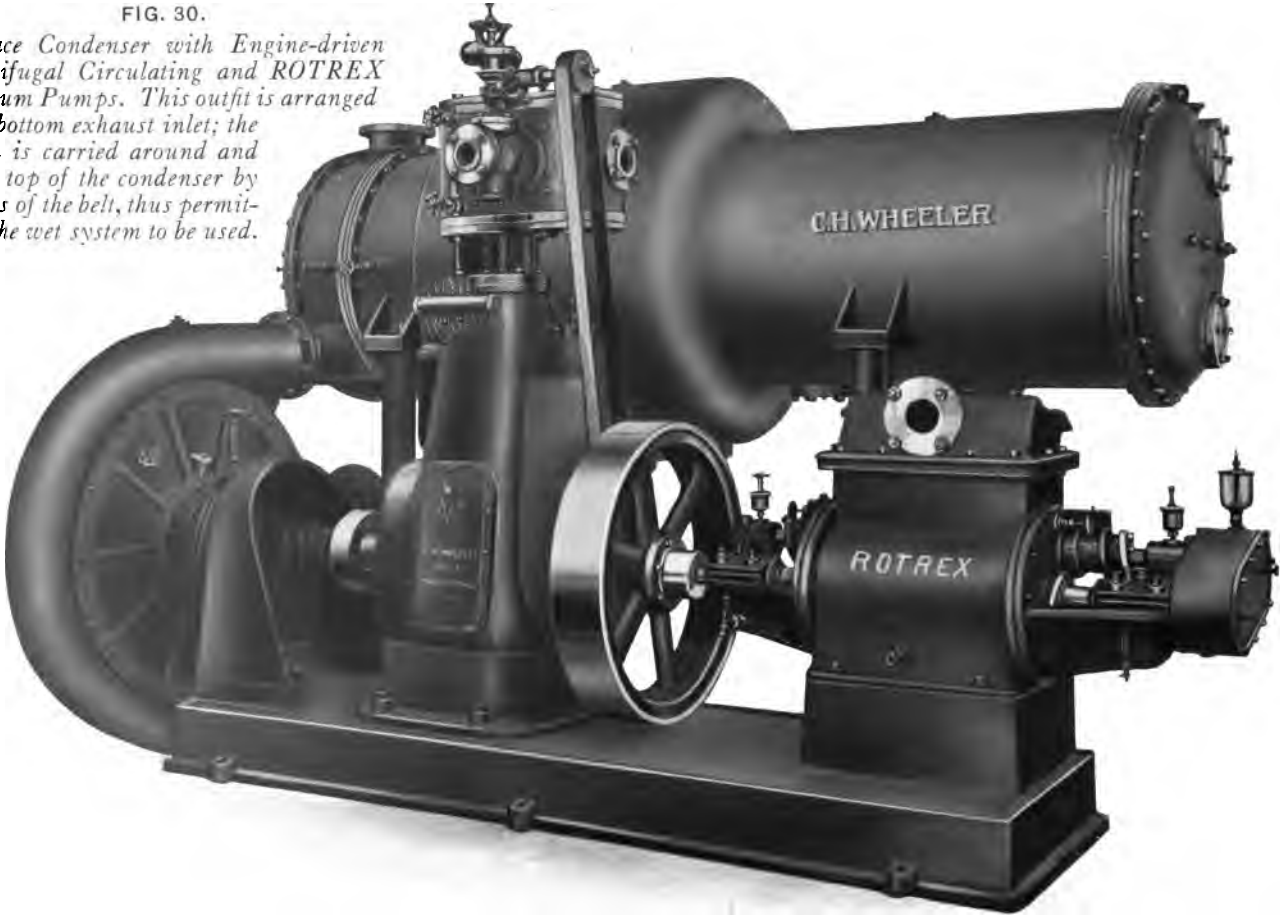


FIG. 29.

Outfit similar to Fig. 28, but a larger unit and showing how the headroom can be minimized for shallow basements.

FIG. 30.

Surface Condenser with Engine-driven Centrifugal Circulating and ROTREX Vacuum Pumps. This outfit is arranged with bottom exhaust inlet; the steam is carried around and to the top of the condenser by means of the belt, thus permitting the wet system to be used.



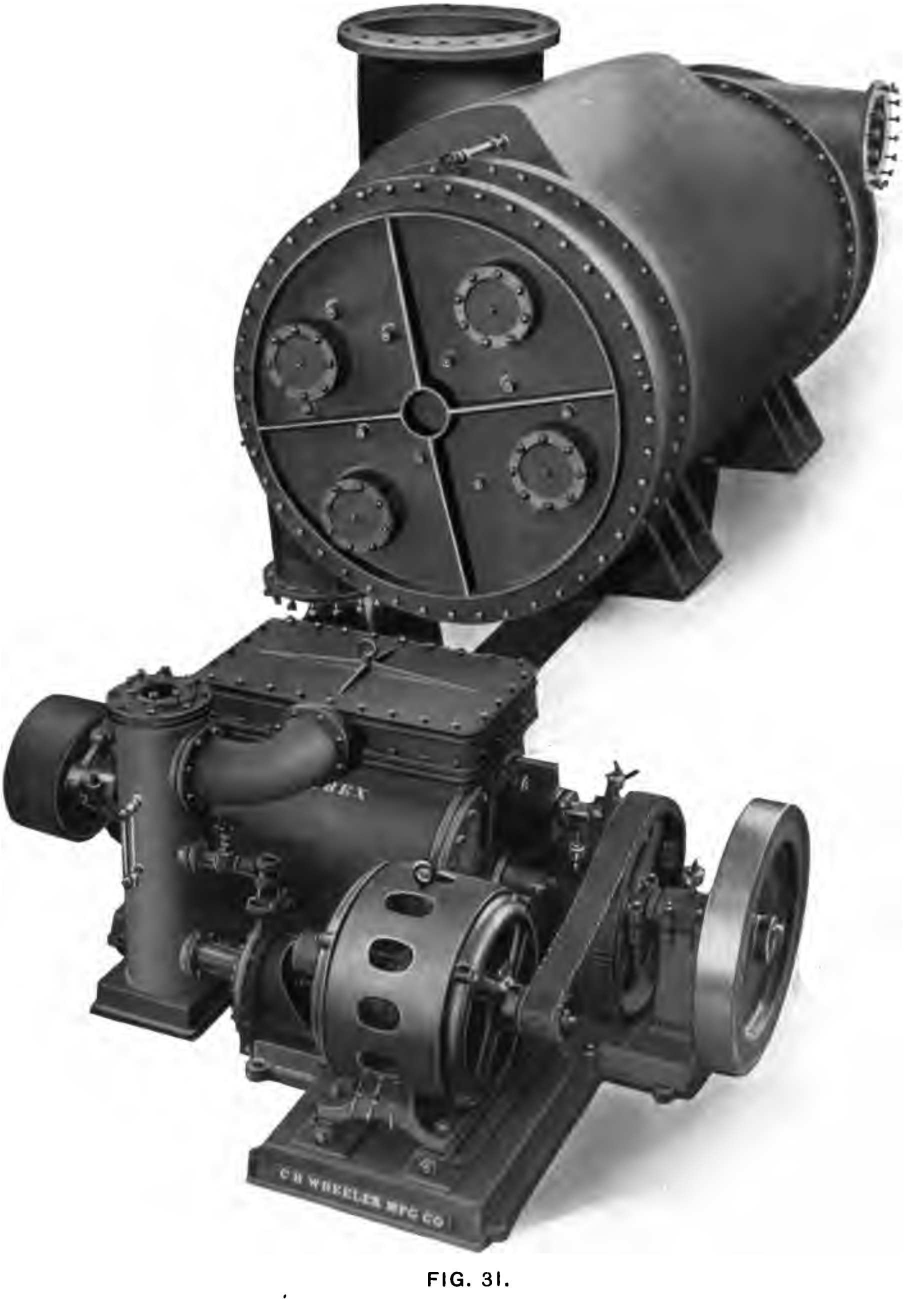


FIG. 31.

3000 KW. Surface Condenser with ROTREX Vacuum Pump and Centrifugal Hot Well Lift Pump, driven from one motor by silent chains.

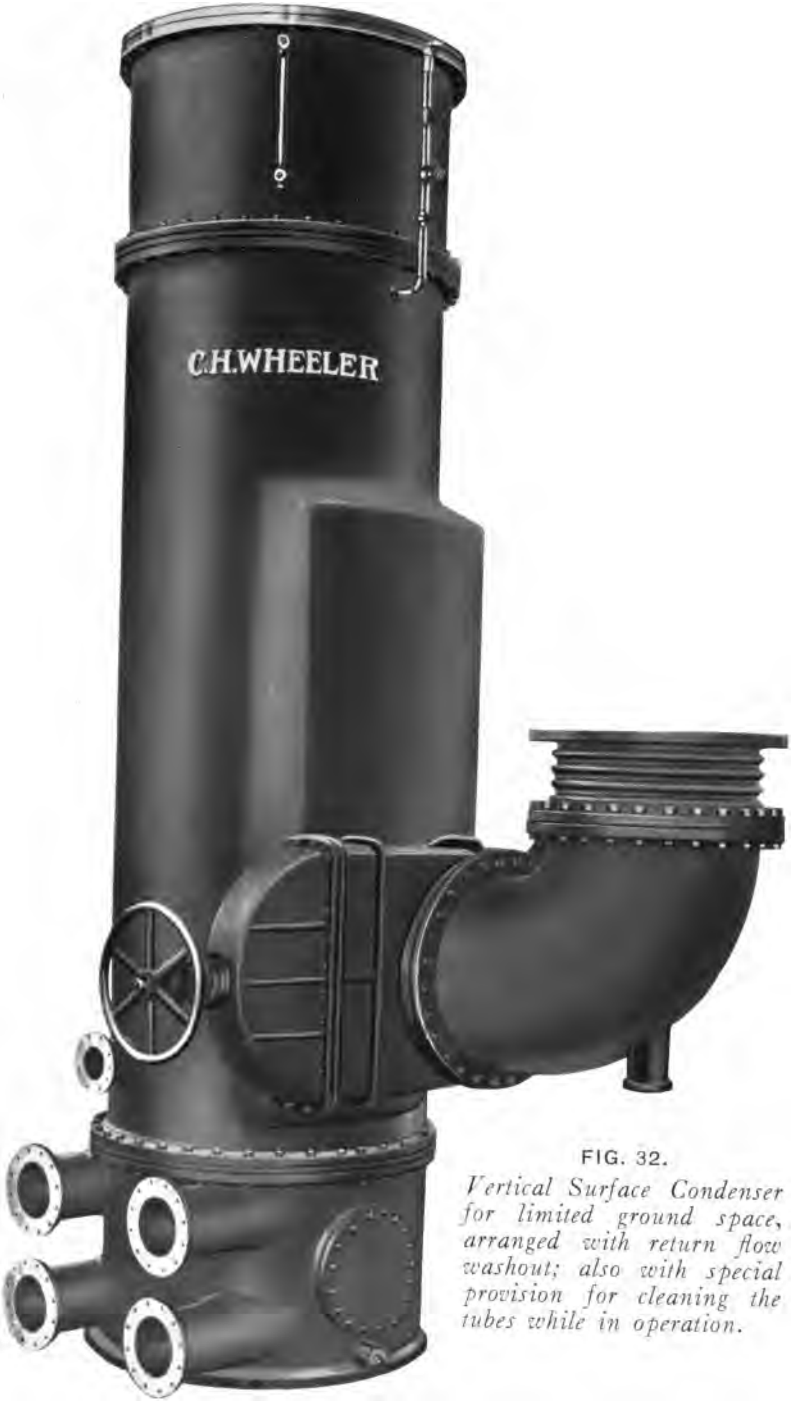


FIG. 32.

Vertical Surface Condenser for limited ground space, arranged with return flow washout; also with special provision for cleaning the tubes while in operation.

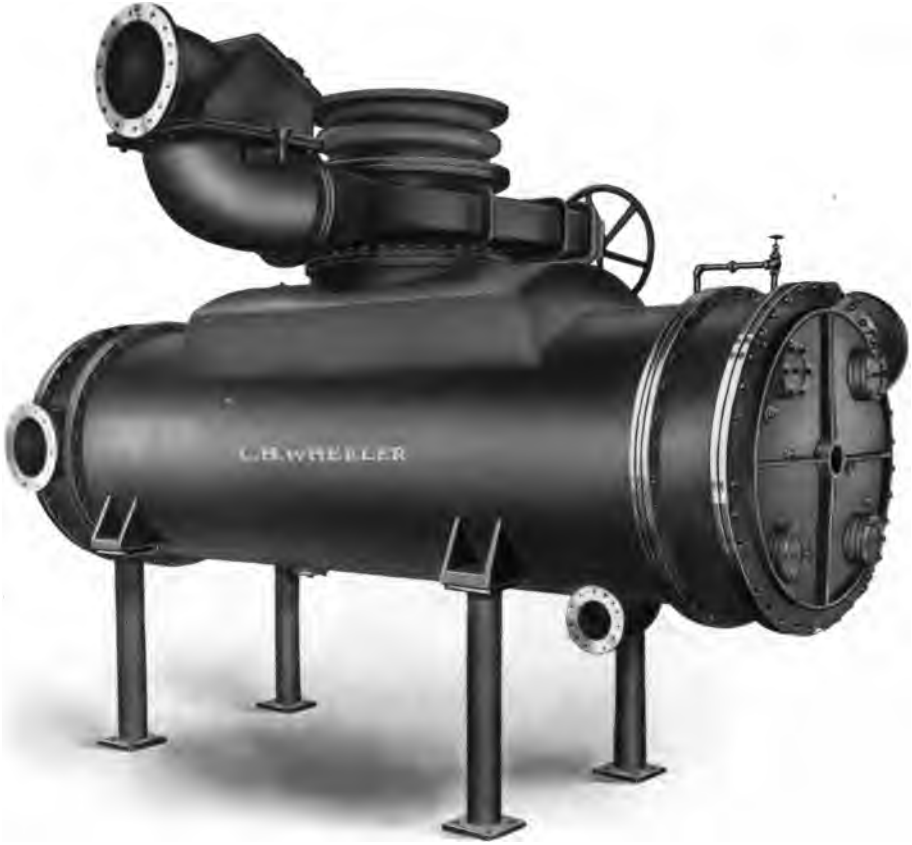


FIG. 33.
Surface Condenser with Multiflex Automatic Relief Valve, Gate Valve and Expansion Joint.

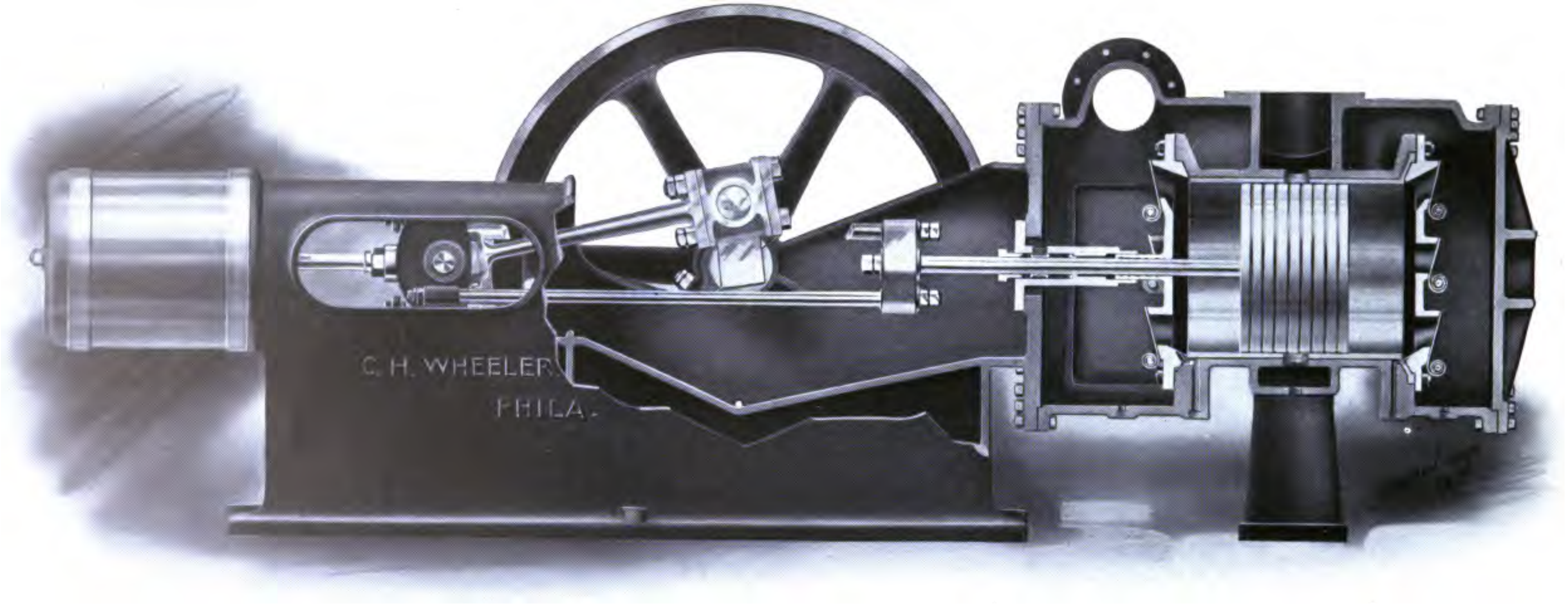


FIG. 34.
Section through Mullan Suction Valveless Air Pump.

CHAPTER V

MULLAN DISPLACEMENT VACUUM PUMPS

(PATENTED)

The vacuum pumps used in connection with steam condensing plants belong to three distinctive types: Reciprocating, rotary displacement and centrifugal entrainment pumps. The first named is represented in its earlier form by the direct acting pump having the steam and air pistons rigidly connected, and taking steam full stroke. This early type is still used for small installations, where low first cost is frequently a determining factor; and in cases where profitable use can be made of the exhaust steam from the pump for heating, drying or like purposes.

The Mullan pump represents a great advance in economy over the direct acting pump, because its motion is governed by crank and fly wheels, thereby making it possible to cut off the steam at an economical point. The steam and air pistons are connected through a cross-head from which the connecting rod and flywheels are driven.

Mullan pumps are of the "suction valveless" type and double acting. The piston creates a vacuum at each stroke until, near the end of its travel, it uncovers a series of ports located around the middle of the cylinder and through which the vapors are drawn into the suction space. This arrangement entirely eliminates suction valves, together with the loss in vacuum attending their operation. The only valves used for discharging the vapors are of the *Gutermuth* type, and mounted on decks bolted to each end of the pump barrel. Large hand-hole openings provide easy access to the valves from either side of the pump cylinder.

Mullan pumps are adapted to operate on either the wet or dry vacuum system. The piston, unlike that of a direct acting pump, has a mechanically limited stroke, allowing the end clearance between piston and valve decks to be reduced to a minimum. When removing air and water vapors only, a small stream of water is sprayed into the suction to reduce the vapor tension and absorb the heat generated by compression, also to lubricate and seal the piston and the discharge valves. Large water spaces are arranged outside the cylinder heads; and their common outlet is above the cylinder. These spaces fill with water, whereby the discharge valves are effectually sealed. The sealing water is utilized as "make-up" for the boiler feed.

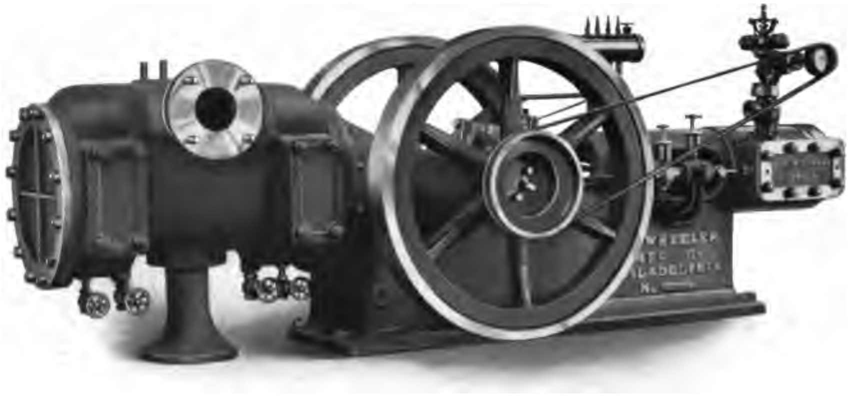


FIG. 35.
A small Mullan Pump.

Mullan pumps operate on the dry vacuum system much better than rotative dry vacuum pumps which depend on the mechanical fit of the valves, aided by lubricating oil, to prevent leakage. Rotative dry vacuum pumps must be water jacketed to absorb the heat of compression, whereby considerable more water is required than with the Mullan type, utilizing the evaporation of a portion of its sealing water to take up the heat of compression. Notwithstanding the jacketing, the pump becomes hot enough to char the oil and cause clogging and leakage of the valves. A further disadvantage of the rotative type is that water from the condenser is liable to get into it, in which event serious injury to the pump may result, owing to the very small cylinder clearances.

When operating on the wet vacuum system, the condensate flows into the Mullan pump by gravity, entering at the top or side. On the discharge stroke the water rises ahead of the piston, compressing the air until both are forced out through the discharge valves. At the end of the stroke the clearance space is filled with water, preventing re-expansion. There are no pockets in which the air can collect, so that a vacuum within a fraction of an inch of the theoretical can be maintained.

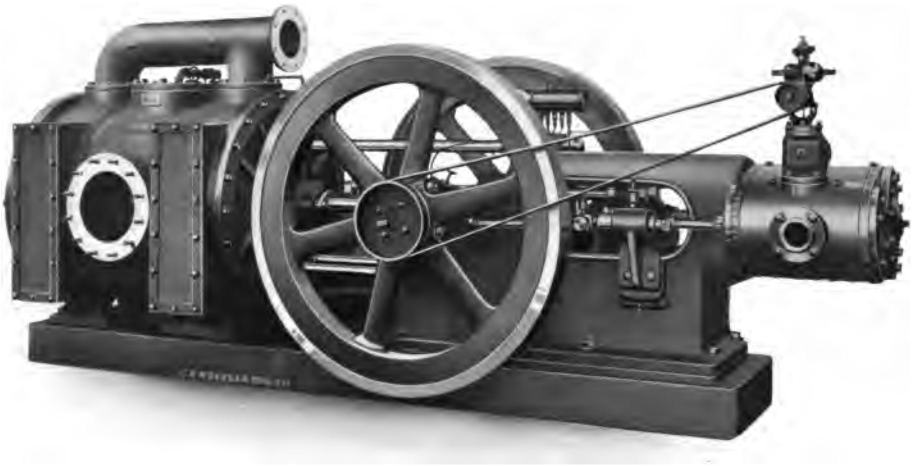


FIG. 36.
Arrangement of a large Mullan Pump.

The *Gutermuth valves,* used in Mullan pumps, constitute an important and striking improvement in valve construction. They are much lighter than the poppet valves often used, and their lift is smaller for a given discharge, hence inertia is minimized and the hammering which frequently breaks poppet valves is eliminated.

MULLAN DISPLACEMENT VACUUM PUMPS

A description of the *Gutermuth* valve will be found in Chapter VII.

As shown in Fig. 34, each valve is sloped in such a way as to discharge the air and water without deflection and with minimum lift.

Instead of using only one valve, the entire inner cylinder head constitutes a brass valve "deck" with as many valves as it can hold. Thus the lift of any individual valve is extremely small, and the valves close instantly at the end of the stroke.

Among the advantages of this type of valve are its simplicity, minimum liability to breakage, small clearances, and the fact that refitting is never necessary. The valves are water sealed, making a tight mechanical fit unnecessary.

The water cylinder is lined with hard brass. The piston is of brass composition, cast very light and with ample surface to insure minimum pressure on the liner. A series of water grooves turned in its surface makes it vacuum tight without the use of piston rings. The piston rod of Tobin bronze is secured in the piston by a taper end, lock nut and pin. It works through a long double stuffing box containing a water seal in addition to the packing, eliminating all possibility of air leakage at that point.

When the Mullan pump is used with a wet vacuum system, and it is necessary to elevate the condensate against a head exceeding 6 or 7 feet, a separate lift pump is attached as shown in Figs. 37, 38 and 39. This water pump is connected to the end of the steam cylinder; and operated by an extension of the steam piston rod passing through the back head, or through an eccentric, operated from the crank shaft, as shown in Fig. 39.

The construction of the steam end is thoroughly first class. The valve gear comprises an eccentric working a D slide valve for the smaller pumps, or a balanced piston valve with self-adjusting snap rings for the larger pumps. The cross-head is cast iron, of the trunk type, provided with taper shoes and wedge adjustment. The wrist pin is hardened steel, ground to size and secured against rotation.

A throttling governor with a safety stop insures against overspeeding from any cause.

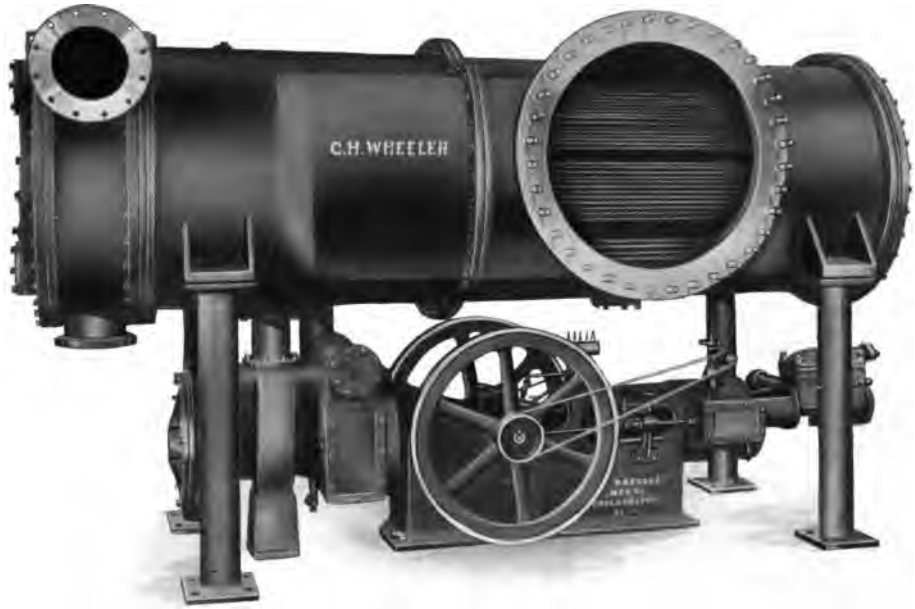


FIG 37.
Surface Condenser mounted over Mullan Air Pump and Tail Pump.

The steam cylinder is lubricated by a sight feed oiler. An oil tank supplies oil by gravity to a wiper which feeds oil to the crank pin; and the crankshaft bearings are lubricated by gravity from the same oil tank. All pumps are tested under steam, vacuum and water; and thoroughly inspected before shipment.

Mullan pumps are furnished for direct steam operation as shown in the illustration; also with pulley or gears for driving from an external source. The latter arrangement is often preferred where the pump is employed for manufacturing purposes.

Mullan pumps are used not only with steam condensers but for numerous manufacturing purposes requiring vacuum. Many of them are installed in the sugar plantations of Cuba, Porto Rico and South America; and the fact that their entire inner construction is of brass renders them particularly well adapted to this work.

Mullan pumps are built in sizes from 8 inches to 30 inches air cylinder bore.

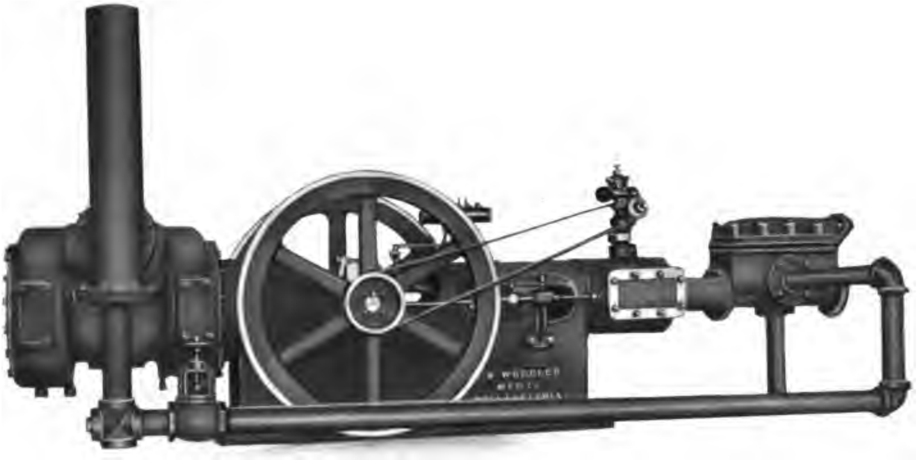


FIG. 38.
Mullan pump arranged with a Hot Well Lift Pump.

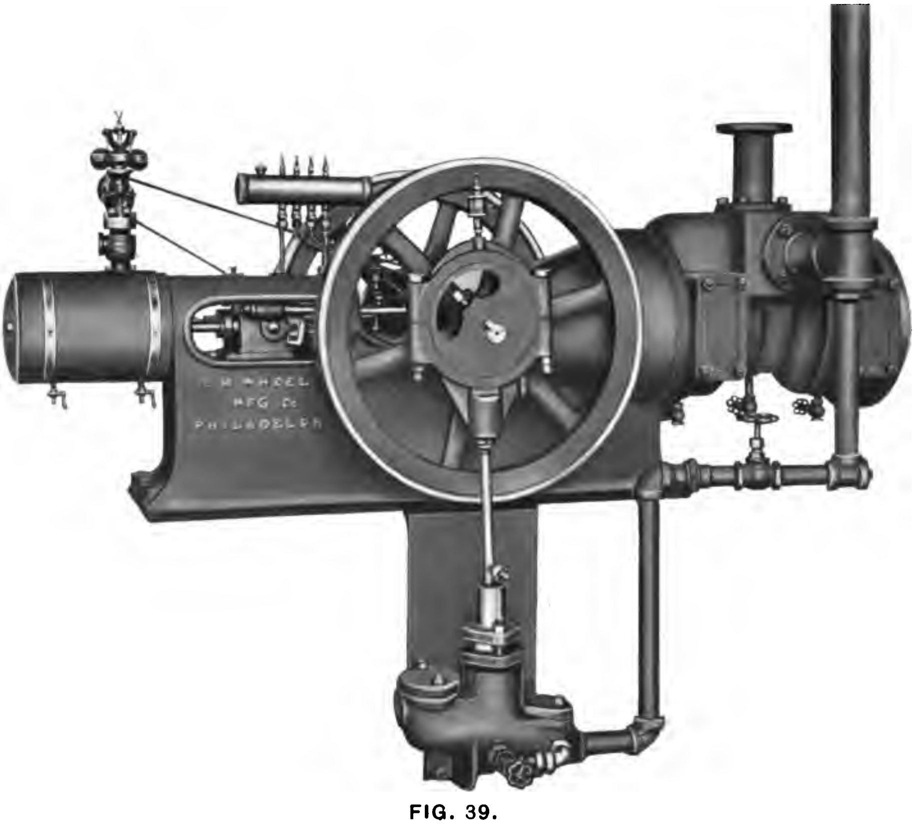


FIG. 39.
Method of connecting vertical Double-Acting Hot Well Lift Pump to a Mullan Pump.

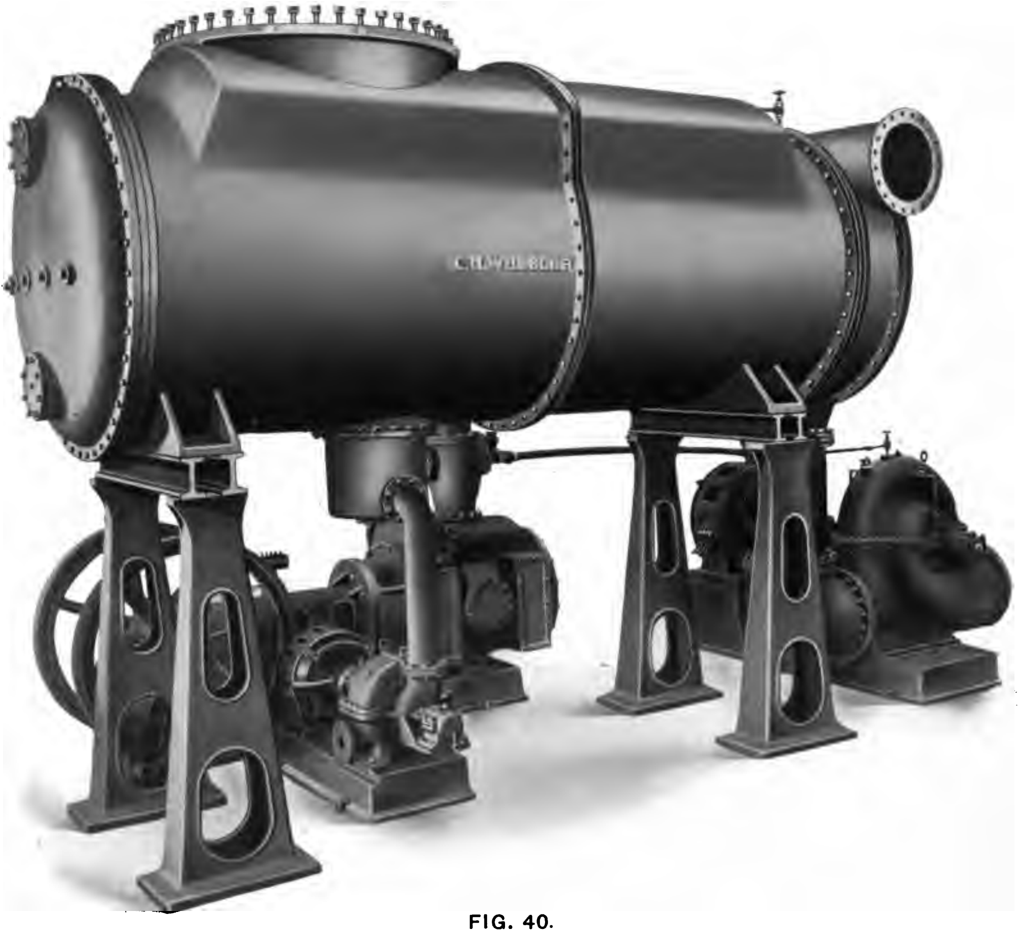


FIG. 40.

Surface Condenser for 5000 KW. Turbine, with one motor driving the Centrifugal Circulating Pump, a separate motor driving the MULLAN Vacuum Pump and Centrifugal Hot Well Pump.

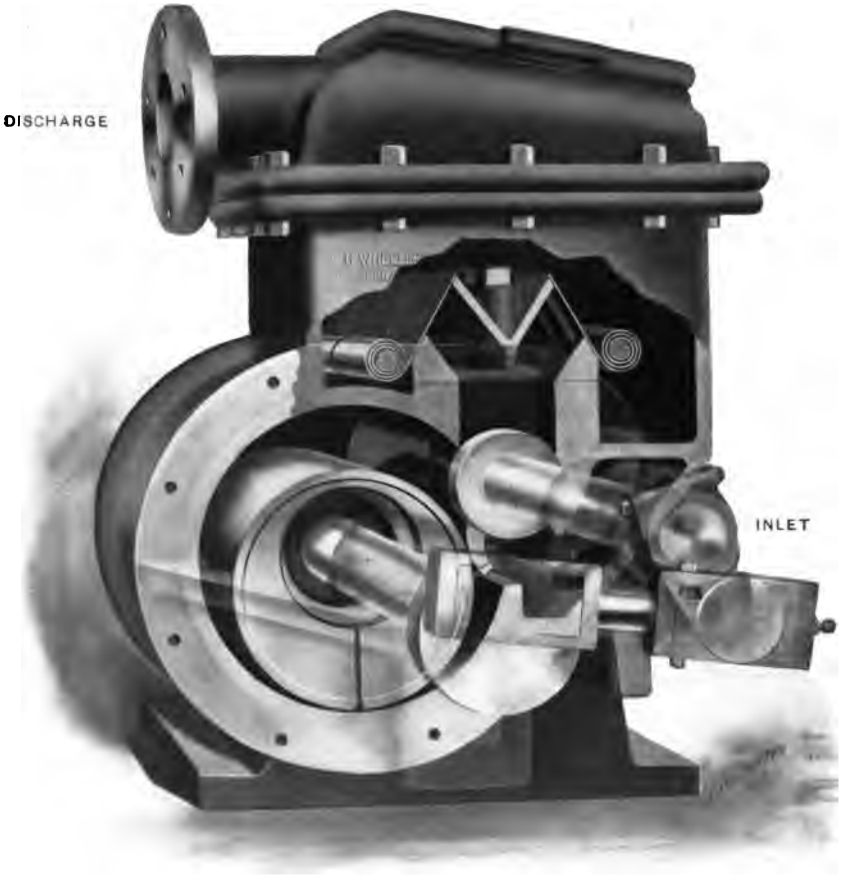


FIG. 41.
Phantom view of ROTREX Vacuum Pump in part section.

CHAPTER VI

PRATT "ROTREX" VACUUM PUMPS

(PATENTED)

Frequently it is desirable to drive the vacuum pump together with the circulating pump and hot well pump from a single engine, turbine or motor. The ROTREX pump lends itself excellently to such an arrangement, by reason of its rotary motion and the possibility to operate at higher speeds than the reciprocating pump.

Sectional view, Fig. 41, shows the interior construction and working of the ROTREX pump. The cylindrical rotor is mounted eccentrically on a shaft supported in outboard bearings. An oscillating cam, operated from the rotor shaft by means of external cranks and connecting rod, separates the suction and discharge sides of the pump cylinder, and follows the motion of the rotor with a small clearance. The rotor is so adjusted as to maintain during its entire rotation the closest clearance with the inside of the air cylinder.

Air is drawn through the intake at the lower right and discharged through the valves on the V shaped deck above the cam. The outlet is at the top.

Freedom from leakage is assured because all clearances are water sealed. The rotor is at no time in contact with the cylinder, nor does the cam touch the rotor, being controlled in its motion by an external driving gear which keeps it very close to, but not quite touching, the rotor.

The surfaces of the rotor and cam are cylindrical, therefore readily and accurately machined. One end of the rotor shaft has a crank, operating through a forged rod another crank on the end of the oscillating camshaft. Both crank pins have large bearings with wedge adjustments for accurately placing the cam. A dust and oiltight casing covers the cam driving gear, thereby preventing oil slinging and greatly increasing the

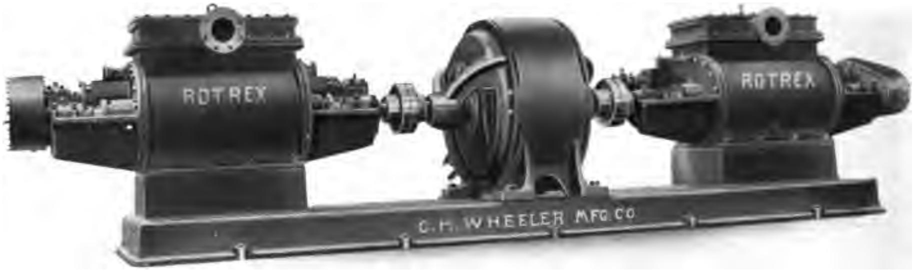


FIG. 42.
Two ROTREX Pumps direct-driven by one slow speed Motor.

durability of the bearings. A gravity sight feed oiler lubricates both crank pins.

A special advantage of the Rotrex pump, due to its design, consists in the possibility of having the suction space in the cylinder open to the condenser all the time, so that the action of the pump does not depend on its producing during part of the stroke a vacuum higher than that existing in the condenser. Consequently there is no loss of volumetric efficiency through re-evaporation of water in the clearance space during the suction stroke; and the vacuum produced corresponds to the temperature of the water present in the pump. The heat generated by compressing the air is absorbed by the water carried around with the rotor, and the compression closely follows the ideal or isothermal curve.

As compared with other types of rotary vacuum pumps, the Rotrex requires considerably less power per cubic foot of free air delivered, for the reason that the rotor works against atmospheric pressure only at the end of each revolution, when the compression is sufficient to deliver the air through the discharge valves. During the rest of its rotation the discharge valves serve as a check, relieving the rotor of the pressure of the atmosphere.

The cast iron cylindrical rotor is internally balanced, permitting operation at speeds up to 600 revolutions per minute, and without appreciable vibration.

The rotor shaft is heavy and made of high grade alloy steel, especially selected for the service. The bearings of both the rotor and camshaft are large and carefully fitted. Cam and shaft are carefully balanced.

The discharge valves, of the *Gutermuth type,* are identical in form and material with those used in Mullan pumps and described on page 71. The valves are designed for easy discharge, and, owing to their extremely light weight are perfectly adapted to the speeds at which ROTREX pumps are operated.

The valve deck is readily accessible through a removable cover plate on top of the pump, provided for that purpose. This permits inspection of the valves and adjustment of their tension by turning the slotted stems which wind up the coiled ends.

ROTREX pumps operate either on the wet or dry vacuum system. When running "dry" a small stream of cooling water is admitted into the intake and carried through the pump to the discharge chamber above the valves, where it collects, filling the space above the valves and forming a water seal for the latter. The surplus water, which is carried out with the air, serves as a make-up for the boiler feed.

Like the Mullan pumps described in Chapter V, ROTREX Pumps are largely used for general manufacturing purposes, as well as in connection with condensers. The first ROTREX

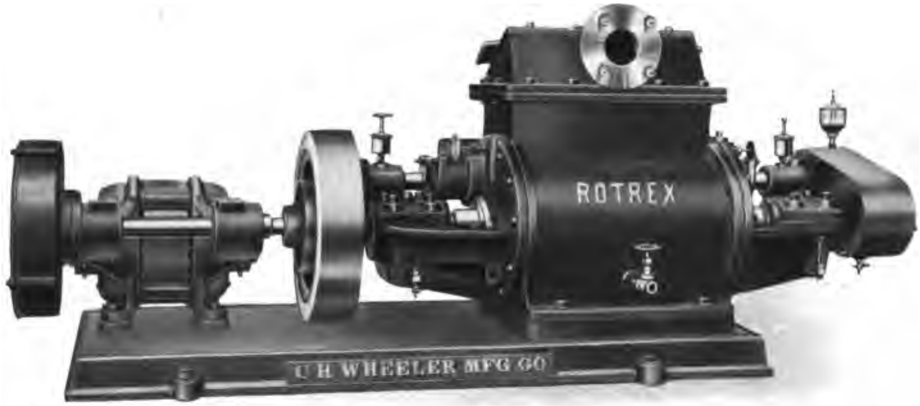


FIG. 43.
ROTREX Vacuum Pump, driven by backgeared Motor.

pump ever built was sold to one of the largest chocolate manufacturers in the world, who has since installed seventeen additional Rotrex pumps, and now uses no other type of vacuum pump in connection with evaporators and the power plant of the factory.

Rotrex pumps can be operated either direct from a steam engine, or by means of belt or gears from an electric motor or turbine. They are built in sizes from 25 to 1000 cubic feet of free air capacity per minute. They will produce any degree of vacuum corresponding to the temperature of the sealing water used.

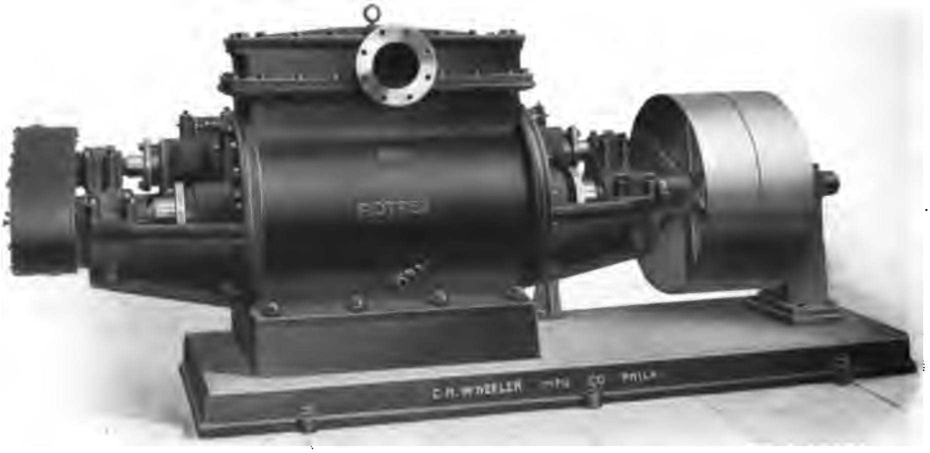


FIG. 44.
ROTREX Vacuum Pump with extended base plate, outboard bearing, and fast and loose pulleys.

Rotrex pumps are particularly desirable where conditions permit both the air and circulating pumps to be direct connected or geared from a single driving unit. For units up to 2500 KW. this gives a very attractive arrangement, combining the simplest possible equipment with very low power consumption.

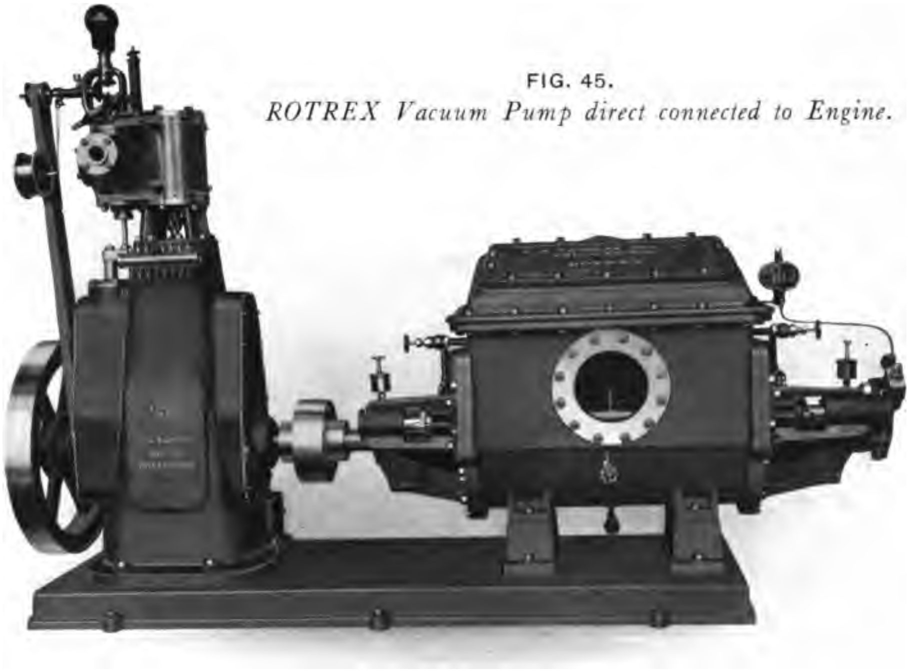


FIG. 45.
ROTREX Vacuum Pump direct connected to Engine.

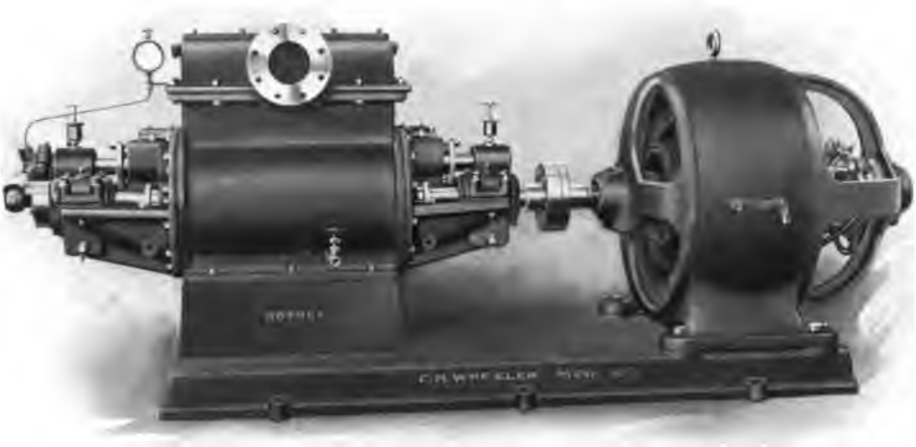


FIG. 46.
ROTREX Vacuum Pump, direct-driven by slow speed electric Motor.

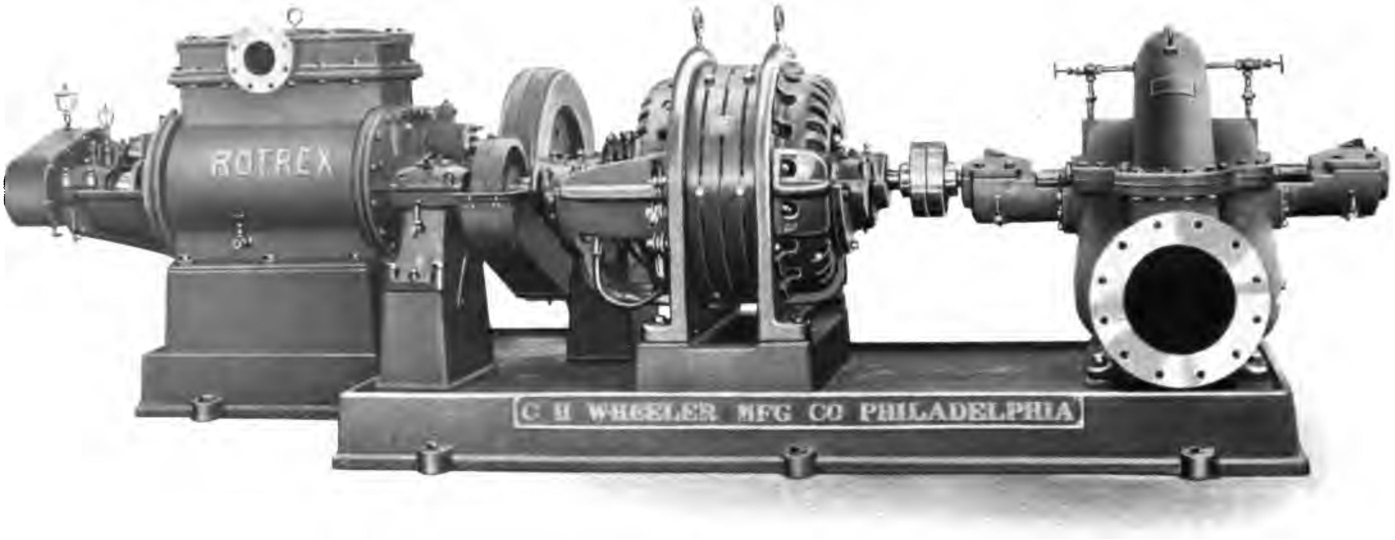
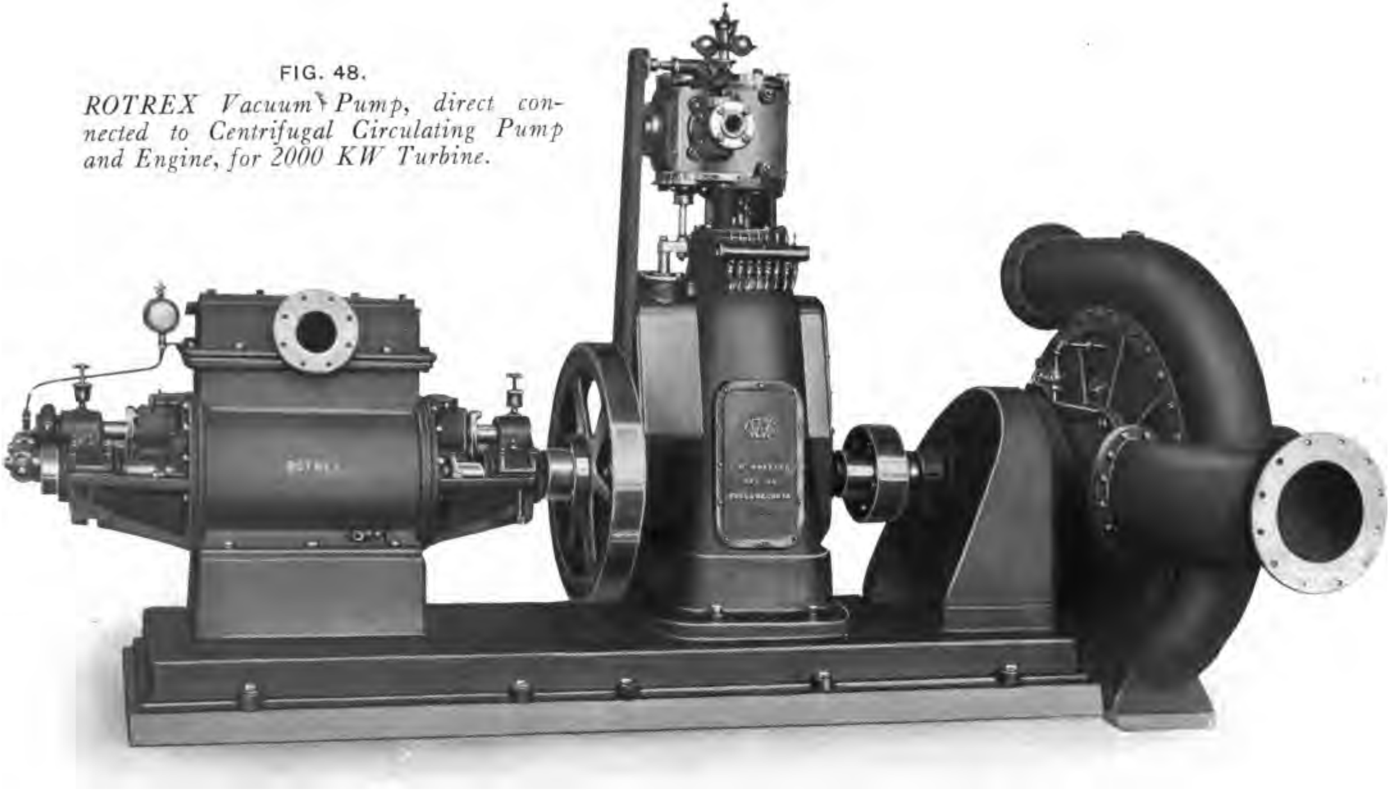


FIG. 47.

ROTREX Vacuum Pump and Centrifugal Circulating Pump driven from one motor. The ROTREX Pump is operated at reduced speed by herring-bone gears enclosed in an oil-tight case (upper half of case removed).

FIG. 48.

ROTREX Vacuum Pump, direct connected to Centrifugal Circulating Pump and Engine, for 2000 KW Turbine.



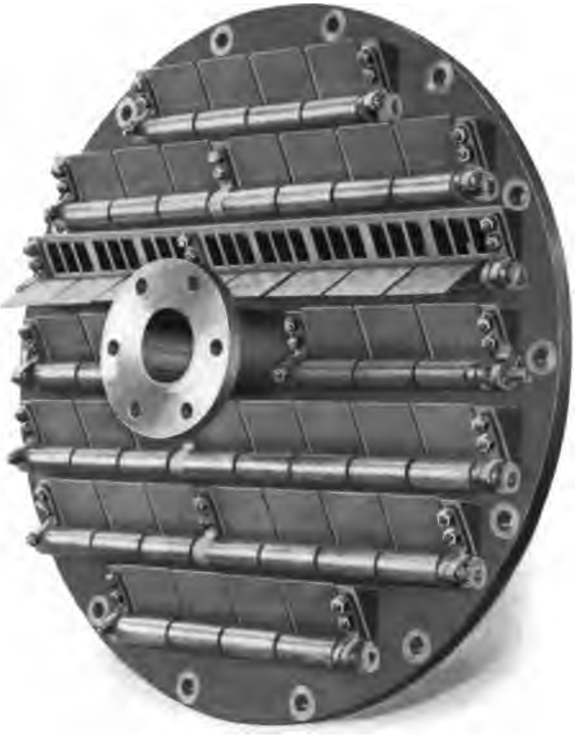


FIG. 49.

CHAPTER VII

GUTERMUTH VALVES

(PATENTED)

An important feature of the displacement type vacuum pump is the design and arrangement of its valves, inasmuch as the successful maintenance of high vacuum is largely governed by their reliability and tightness.

To meet all the essential requirements, including light weight necessary at high speeds, the C. H. WHEELER MANUFACTURING COMPANY adopted a type of valve invented by Professor M. F. Gutermuth of the University of Darmstadt, Germany.

This valve consists of a plate made of phosphor bronze, or special steel of high tensile strength and elasticity, coiled at one end as shown in Fig. 50, the other end being left flat to serve as the flap of the valve. The inner end of the coil is held in a slot of the spindle, the latter being secured in position and locked by means of a ratchet. The valves are usually mounted in groups on a bronze valve rod, which holds them

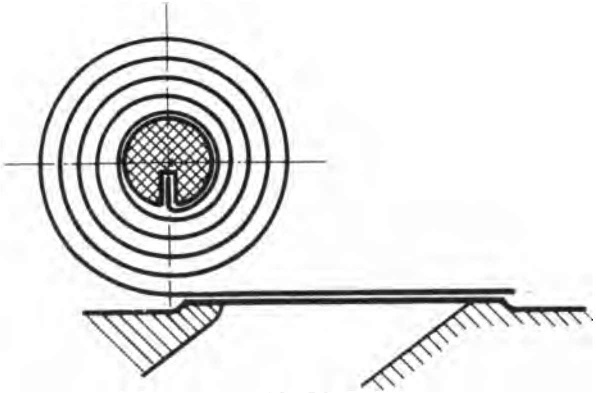


FIG. 50.

against the seat. Provision is made for adjusting this rod, whereby the desired tension can be put on the valve springs.

The Gutermuth valve is quite similar in practice to the hair spring in a watch; both equally elastic and required to withstand coiling and uncoiling countless millions of times. The distinguishing feature of the Gutermuth is the fact that it may be opened to any angle without straining the material; *i.e.*, the elasticity of the entire length of the coil is pressed into service and without friction, insuring positive action without guides or guards, as the flap will return to its original position on the valve seat, no matter how wide it may have been forced open. With the lifting from its seat the valve has also a wiping motion, which distinguishes it from all other flap valves. It is this motion which insures its smooth working, at the same time minimum pressure is required to open it.

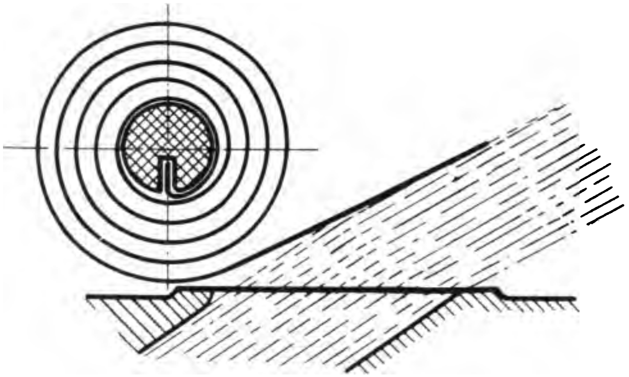


FIG. 51.

Another advantage of the Gutermuth valve, as against the ordinary type of valve, is the fact that no turning of the jet takes place and no eddies are formed, air and water passing through the port without deflection, see Fig. 51.

The Gutermuth valve is used in the Mullan and ROTREX vacuum pumps (see Chapters V and VI). Figs. 49 and 54 show valve decks for Mullan pumps; Fig. 52, a similar deck for a ROTREX pump with valves closed; and Fig. 53 with valves thrown wide open to show the port openings. The arrangement of valves on the deck is clearly illustrated in the phantom view on page 62.

By special agreement with Professor Gutermuth, the C. H. Wheeler Manufacturing Company control the United States and Canadian patents for the exclusive use of his valve in its application to vacuum pumps.

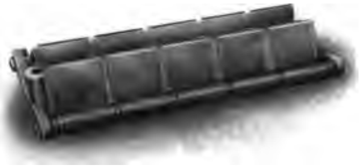


FIG. 52.

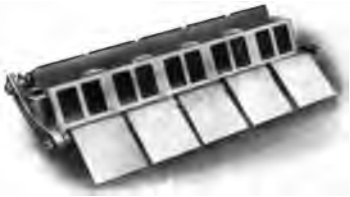
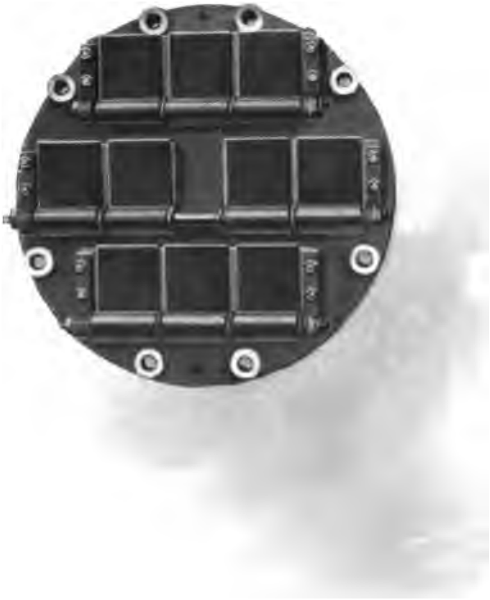


FIG. 53.

FIG. 54.



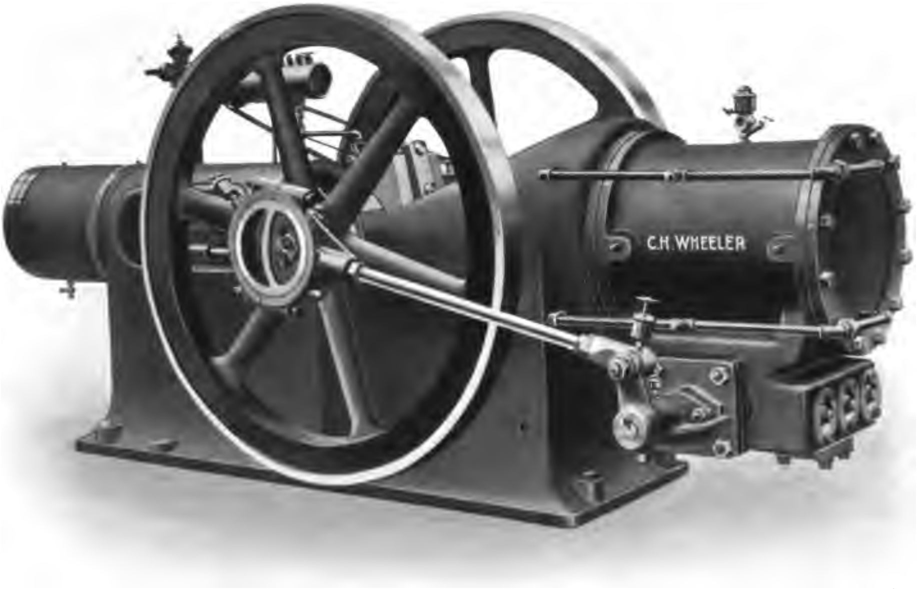


FIG. 55.

Rotative Dry Vacuum Pump.

CHAPTER VIII

ROTATIVE DRY VACUUM PUMPS

With high vacuum condensing equipments both of the surface and jet types, it is sometimes desired to remove the air by means of a piston type dry vacuum pump.

The admission to and discharge from the vacuum cylinder are controlled by means of a semi-rotative valve provided with an equalizing port arranged to connect the two ends of the cylinder at the completion of each stroke after the closing of the suction port, thus almost eliminating the effect of clearances and preventing loss of efficiency which would otherwise result from the re-expansion of the vapors at the beginning of the suction stroke.

The discharge valves are of the Poppet Spring Loaded Type and readily accessible. All valves are located underneath the air cylinder to insure thorough draining at all times.

The inlet valve or valves are operated from the crankshaft by means of eccentric and rod operating a crank on the end of valve rod.

The end covers of the vacuum cylinder are provided with water jackets, and so designed as to reduce the cylinder clearances to a minimum. The crank end cover is provided with deep stuffing box and gland containing a sealing cage and connection for water seal.

The valve chamber is cast integral with the air cylinder; and fitted with a cast iron removable bushing ground to size and with machined ports for the reception of the rotative mechanically operated valve.

The smaller pumps have the steam and air cylinders placed at opposite ends of the frame, with crankshaft and flywheels in the center. The larger machines are built with the cylinders in tandem and fork frame, the vacuum pump being driven by an extension of the steam piston rod through the back cover.

All moving parts are provided with adjustments to take up wear; and every pump is equipped with a complete system of lubrication to insure an adequate and continuous oil supply to all bearings and working surfaces.

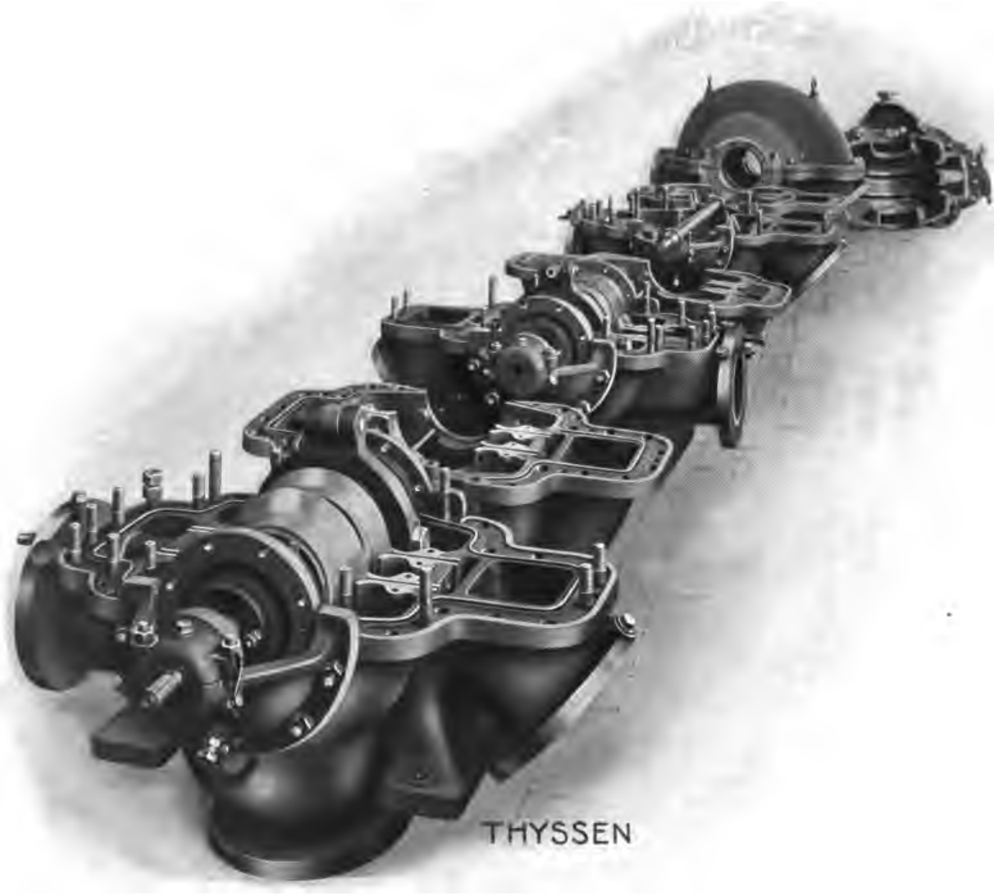


FIG 56.

CHAPTER IX

THYSSEN ENTRAINMENT VACUUM PUMPS

(PATENTED)

The Thyssen Vacuum Pump combines the best features of a rotary entrainment pump with the simplicity of a centrifugal pump.

Its introduction in Germany and other European countries was welcomed as a valuable addition to condenser auxiliaries; and the superiority of the pump has insured its recognition and success in the United States.

The working principle upon which the Thyssen pump is designed consists of two continuous water films, discharged radially through annular nozzles surrounding the periphery of two impellers supplying the necessary entrainment water under pressure. These water films entrain the air through secondary nozzles, in which the kinetic energy of the water and vapor mixture is gradually converted into pressure, and the mixture discharged against the atmosphere.

The entrainment water is supplied from a tank, usually located under the pump, and circulated through the pump over and over again. The entrainment air pump may in fact be compared to a centrifugal pump, devoid of the clearances which, owing to re-evaporation and expansion, limit the volumetric efficiency of all forms of reciprocating air pumps. It is therefore capable of producing a vacuum practically corresponding to the temperature of the water present. Unlike an ordinary air pump, handling partly cooled condensate with the air, the entrainment pump can produce a vacuum materially higher than that in the condenser. The cold entrainment water instantly condenses the water vapor in the mixture coming from the condenser, and, as no re-evaporation is possible, the entrainment pump serves as a secondary condenser in series with the main condenser. It is therefore well adapted to operate successfully with parallel flow jet condensers and with non-refrigerated air vapor mixtures generally.

A serious defect in the ordinary entrainment type vacuum pump follows the necessity of using the vacuum to draw the entrainment water into the pump; as any break in the vacuum would let air into the pump and therefore into the condenser, necessitating running the main unit non-condensing until the air pump could be again primed and started. This objection has been evercome in the Thyssen pump, which does not depend

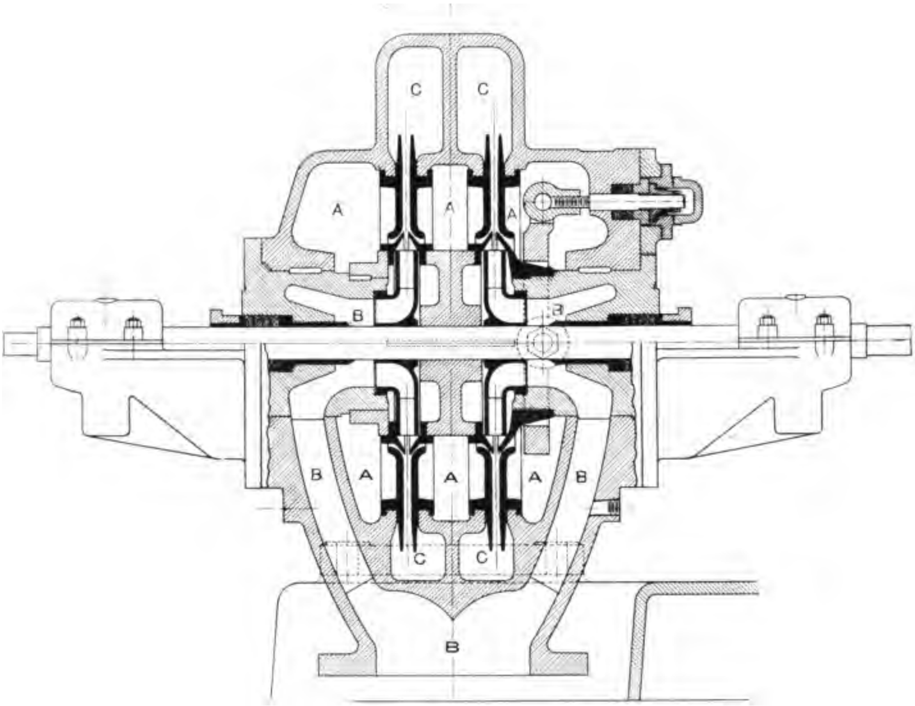


FIG. 57.

THYSSEN *Entrainment Vacuum Pump in section. AA, air suction chambers. BB, water suction passages. CC, water and air discharge passages.*

on the vacuum to lift the water, so that a momentary drop in vacuum cannot affect the proper working of the pump.

Fig. 57 shows a cross section of the pump, the casing of which is divided horizontally, similar to that of a centrifugal pump. This casing contains two side suction water impellers mounted right and left hand on the shaft, the water being supplied at "B" and discharged through nozzle rings extending around the periphery of the impeller wheels. The water issues from the discharge nozzles in thin annular sheets and is delivered to the stationary entrainment nozzles, converting the volocity of the mixture into pressure after which it passes to the volute and discharges in the regular way. The air is admitted through the opening at one end of the pump, and upon passing to both sides of each of the discharge nozzles, is drawn into and forced through the entrainment nozzles by the velocity

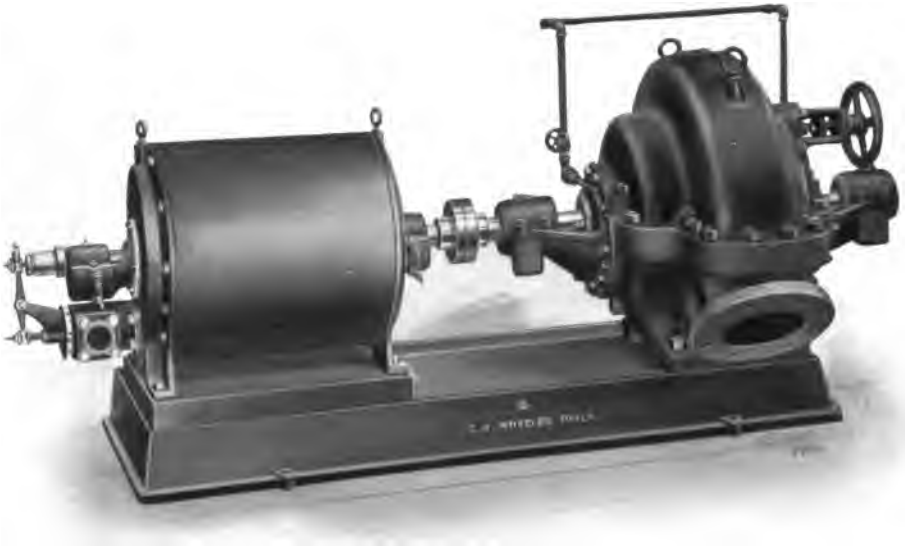


FIG. 58.
THYSSEN *Pump, Turbine driven.*

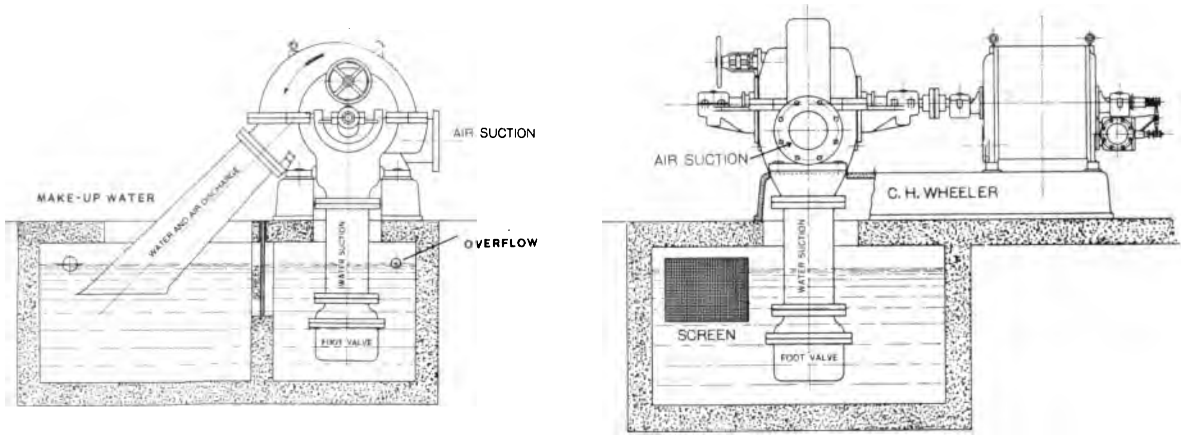


FIG. 59.

General arrangement of turbine driven **THYSSEN** *Pump over tank containing the entraining water.*

of the water. The external view of the pump, Fig. 59, further illustrates its construction.

An important feature of the Thyssen pump, and to which its high efficiency is largely due, is found in the arrangement of the discharge nozzle rings. From the illustration it will be seen that each nozzle consists of two separate rings. Starting from the left hand side, one ring is attached firmly to the casing, the two following rings are fastened to a central disc, keyed to the shaft, and the fourth ring forms a sliding sleeve adjustable from the exterior of the pump. The rotating element includes the shaft with two impellers and the central disc, carrying the second and third rings of the discharge nozzles. A slight axial movement of the rotating element is provided for, permitting self adjustment of the ring passages. This axial movement has another important function, viz., to allow the passage of any small particles of foreign matter which might get through the screens and enter the pump. If, for instance, foreign matter was caught in one of the ring passages, the water pressure on that side would increase, due to the obstruction of the flow, causing the central disc to move axially a sufficient amount to allow the obstruction to pass between the nozzle rings at that point, after which the disc would automatically return to its balanced position. The fact that the operation of the Thyssen pump is not affected by small particles of foreign matter, as is the case with some entrainment pumps, is a most valuable feature.

It will be further noted that, by an outside adjustment, the width of the passage between the nozzle rings can be varied, which permits circulating the correct amount of water at all times, depending upon the load, water temperature, speed, etc., thereby insuring the best economy for a given operating condition. This, of course, does not mean that continuous adjustment is necessary, but merely that adjustments can be made should the water temperature vary sufficiently to justify occasional changes.

Where space is limited or where for any other reason it may not be desirable to provide a tank for the entrainment

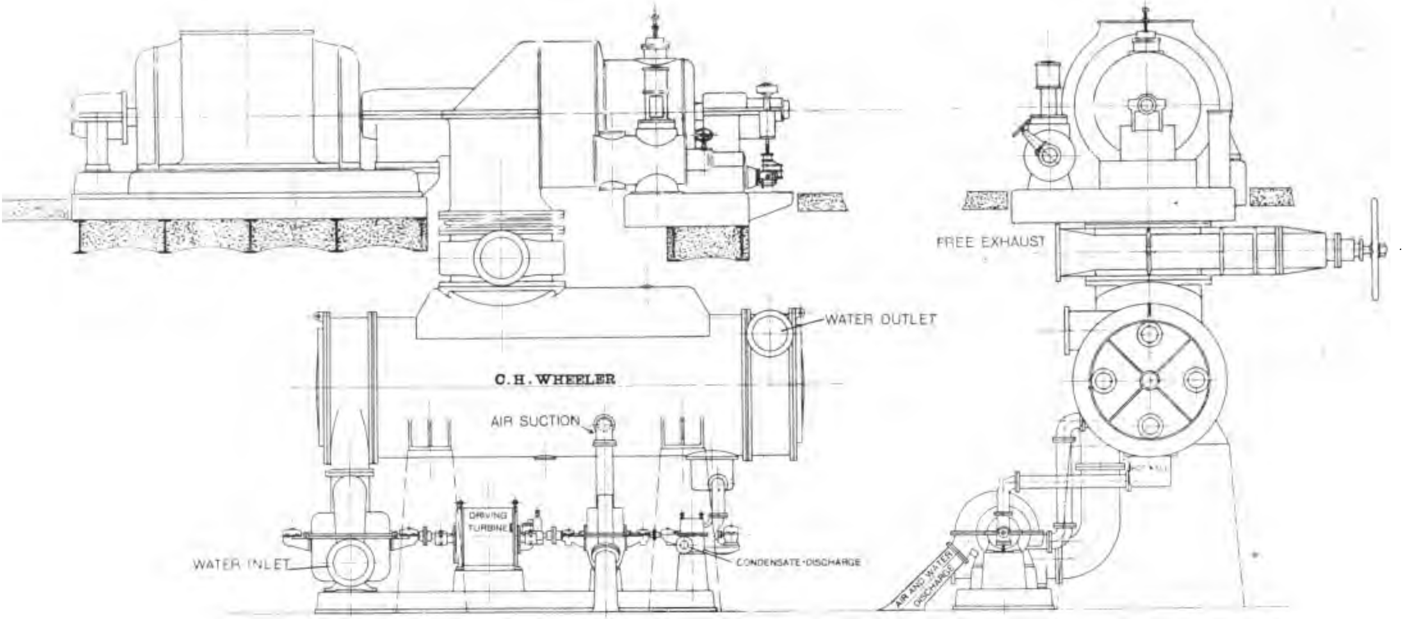


FIG 60.

Steam Turbine with Surface Condenser and turbine-driven Centrifugal Circulating Pump, THYSSEN *Air Pump, and Centrifugal Hot Well Pump. Also showing Gate Valve and Expansion Joint.*

water, the Thyssen pump can be operated in parallel with the circulating or injection water; *i.e.*, the necessary water supply to the air pump can be taken from the circulating line to the condenser, and discharged from the air pump into the discharge from the condenser.

The compactness, simplicity and low cost of Thyssen pumps render them specially adapted for large condenser installations; and their superior efficiency insures economy in operation.

Thyssen pumps are built in all sizes up to a capacity sufficient to operate with turbines of 15,000 KW.

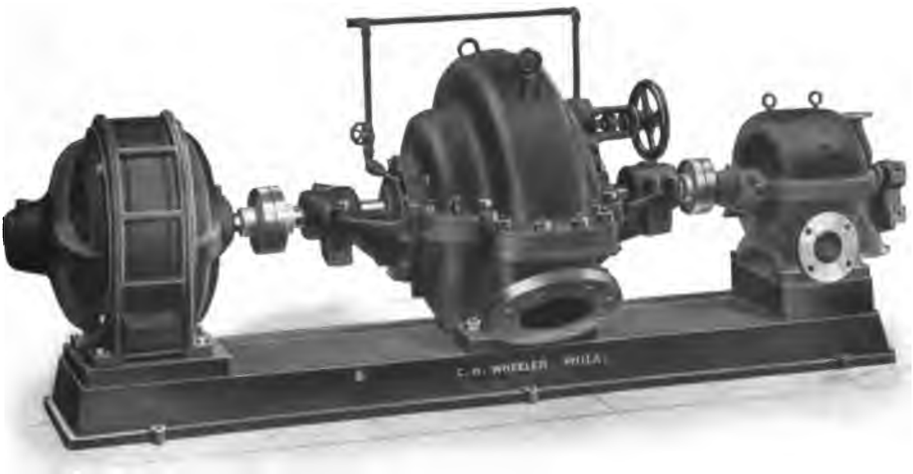


FIG. 61.

Motor driven THYSSEN *Pump, with direct connected two-stage Centrifugal Hot Well Pump, for use with Surface Condenser.*

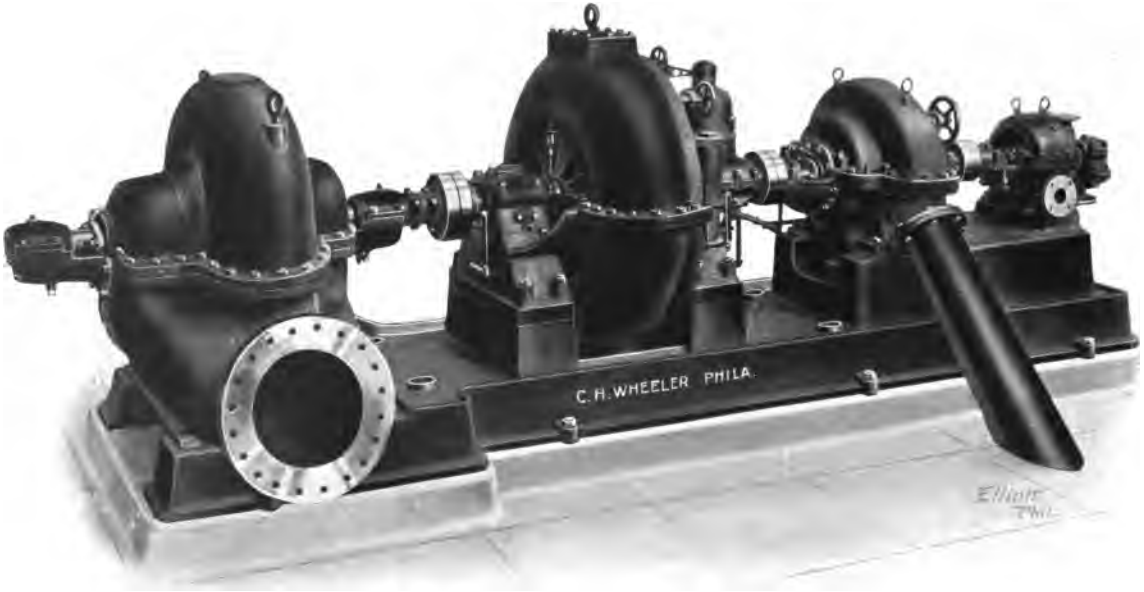


FIG. 62.
A combination set comprising Centrifugal Circulating Pump, THYSSEN *Air Pump, and two-stage Centrifugal Hot Well Pump, all direct driven by a steam Turbine.*

THYSSEN VACUUM PUMPS

Messrs. Thyssen & Co., of Mulheim-Ruhr, Germany, who developed the air pump herein described, operate one of the largest and best equipped plants in Europe, which, together with the steel works, rolling mills and coal mines controlled by them, employ over seventy thousand men and rival in magnitude the famous Krupp Works.

The Engineering Department of Messrs. Thyssen since its establishment in 1871 is one of the striking examples of the growth of German industries in recent years. The output includes large gas engines, steam turbines, mining machinery, condensing plants, cooling towers, etc. It was the rapid development of their steam turbine business which necessitated the design of suitable condensers and evolved the type of air pump herein described. The first two pumps built by Thyssen were installed in their own power plant and subjected to a severe endurance test, the results of which justified the manufacture of this machine on a large scale.

The C. H. Wheeler Manufacturing Company obtained, by a special agreement with the Maschinenfabrik-Thyssen & Co., their exclusive representation in the United States and Canada under the patents taken out in those countries.

The C. H. Wheeler Manufacturing Company build a complete line of Thyssen Air Pumps identical in construction, material and workmanship with the high grade pumps made by the Thyssen Company.

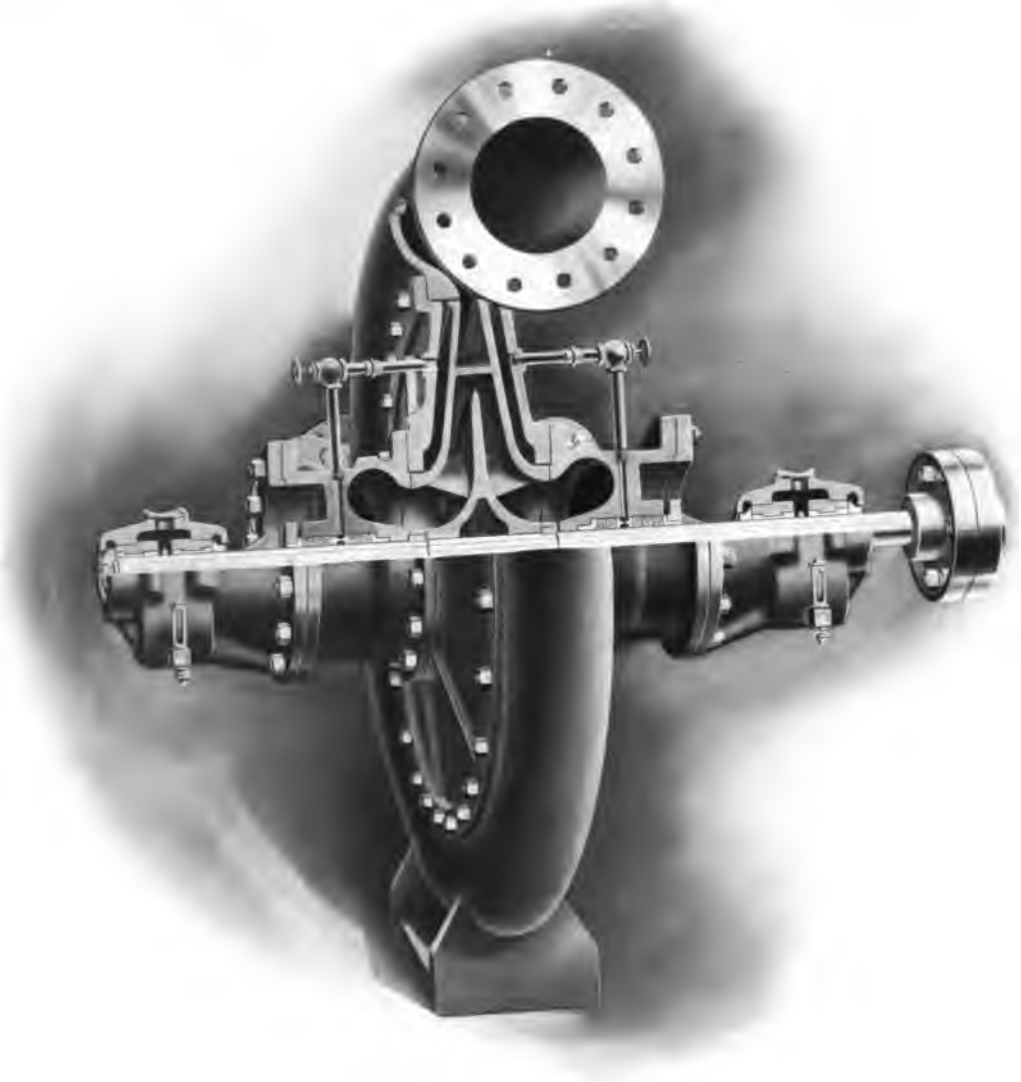


FIG. 63.
Slow Speed Centrifugal Pump in half section.

CHAPTER X

CENTRIFUGAL CIRCULATING PUMPS

By reason of their compactness, simplicity and balanced rotary motion, centrifugal pumps have supplanted all other types for water circulating and removal purposes, except in some small condenser installations where direct acting pumps can be used to advantage. It is also usual to combine centrifugal air and circulating pumps with the centrifugal hot well pump, in order to drive the three units from a single motor or turbine.

The total head (the sum of the suction, discharge and frictional heads) to be overcome by the removal pump of a jet condenser is seldom more than 30 feet, while the friction head of a surface condenser averages from 5 to 15 feet, requiring special designs to obtain good efficiency under these low pumping heads.

C. H. WHEELER Centrifugal Pumps are built in three different types, respectively: for low, moderate and high speeds. Pumps of the first type are usually engine driven, with or without ROTREX pumps in combination. Pumps of the second type are motor driven, and those of the third are designed for direct connection to steam turbines.

Low Speed Pumps

A Centrifugal Pump for low speeds is shown in Fig. 63. The volute is cast in one piece, with discharge opening pointing in any direction desired in the plane of the impeller. This opening is flanged and drilled for piping connection. Both sides of the volute are open, faced and fitted on close centers with stud bolts to receive the side covers.

The impeller is of cast iron, or when specially ordered of brass, carefully balanced and with smooth waterways. It is of the enclosed design, with vanes carefully shaped to give maximum efficiency for specified conditions, and it is secured on the shaft by means of press fit and key. The shaft is so dimensioned as to avoid vibration; and brass covered through the water passages and stuffing boxes to prevent corrosion.

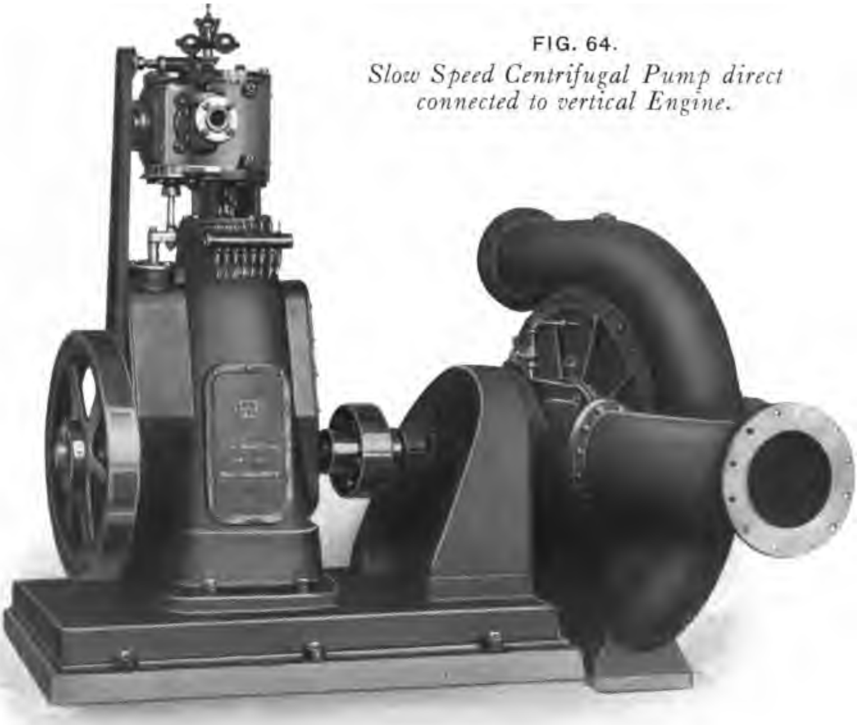


FIG. 64.
Slow Speed Centrifugal Pump direct connected to vertical Engine.

The side covers are of cast iron, well ribbed for stiffness, and accurately faced to fit the volute and suction heads.

The suction heads containing the stuffing boxes carry the water to the eye of the impeller on each side. The stuffing boxes are extra long and fitted with a grooved brass water sealing ring to prevent air leakage around the shaft. The two suction heads are connected by a Y-shaped suction branch, the double suction arrangement being used to eliminate end thrust of the impeller and consequent wear.

The bearing brackets are flanged and bolted to the suction heads. They contain oil wells, with gauge glasses and oil rings. The bearings are babbitt lined and accurately bored to gauge.

The pump is connected to the engine by a shrouded flange coupling, pressed and keyed on the shaft. Every pump is tested before shipment, when its head, capacity and efficiency are carefully determined.

For manufacturing and other special purposes these pumps may be furnished with pulley for belt drive, instead of flange couplings.

Moderate and High Speed Pumps

These pumps differ from the low speed pumps, in having the casing horizontally divided, as illustrated in Figs. 65 and 66. The suction and discharge openings are contained in the lower half of the casing, as the illustrations show, although the pump may be reversed end for end in order to run in the other direction. All the water passages are designed to provide ample area and minimize friction losses.

The impeller is made of brass, or other composition to suit water conditions, and of the shrouded design, accurately balanced and with waterways carefully designed and finished to minimize friction. Removable brass rings are provided on the impeller hubs to reduce water slippage and aid in securing high efficiency. The shaft is of high grade steel, fitted with brass sleeves extending through the stuffing boxes, and the impeller is pressed and keyed on. The stuffing boxes are water sealed in the same manner as those of the low speed pumps already described.

The main bearings are carried in brackets, bolted to the lower half of the casing; they are babbitt lined and provided with oil rings, reservoirs and oil gauges.

The coupling is of high speed flexible design, with shrouded flanges, keyed and pressed on the shaft. Every pump is tested before shipment.

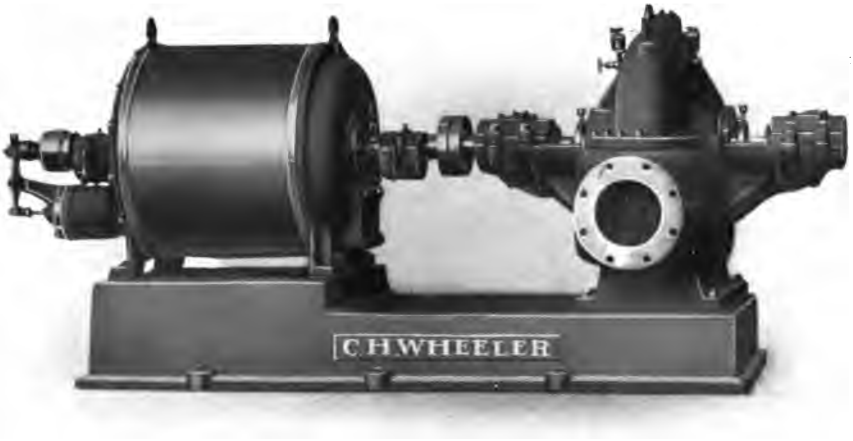


FIG. 65.
High Speed Centrifugal Pump direct connected to steam Turbine.

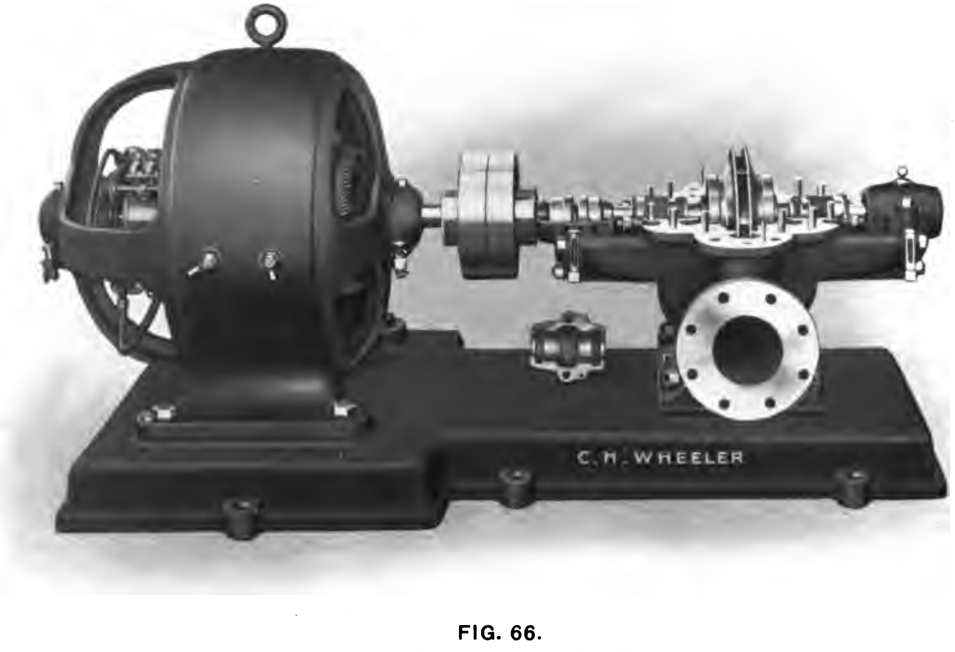


FIG. 66.
Small High Speed Centrifugal Pump with direct connected Motor.

Hot Well Pumps

Guided by the realization that "a chain is no stronger than its weakest link," the C. H. WHEELER MANUFACTURING COMPANY give special attention to the design of Centrifugal Hot Well Pumps, to insure their reliable operation.

These pumps operate in two stages, thus having only one stuffing box under vacuum instead of two; also dividing the duty of handling the hot water in a manner ensuring steadiness and uniformity of flow.

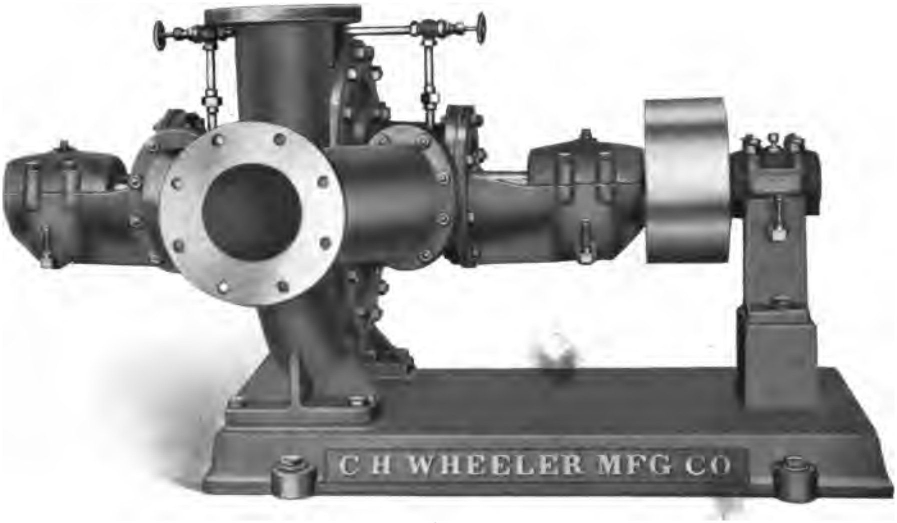


FIG. 67.

Centrifugal Pump for moderate speeds, with extended shaft, outboard bearing, and pulley for belt drive.

The efficiency of the stuffing box depends both on the adequacy of its water sealing and its being kept cold at all times; the usual water sealing is supplemented by a special arrangement for cooling the gland itself. For this purpose the gland is cast hollow and a stream of cold water is run through it, thereby averting any possibility of the stuffing box losing its water seal and admitting air through overheating.

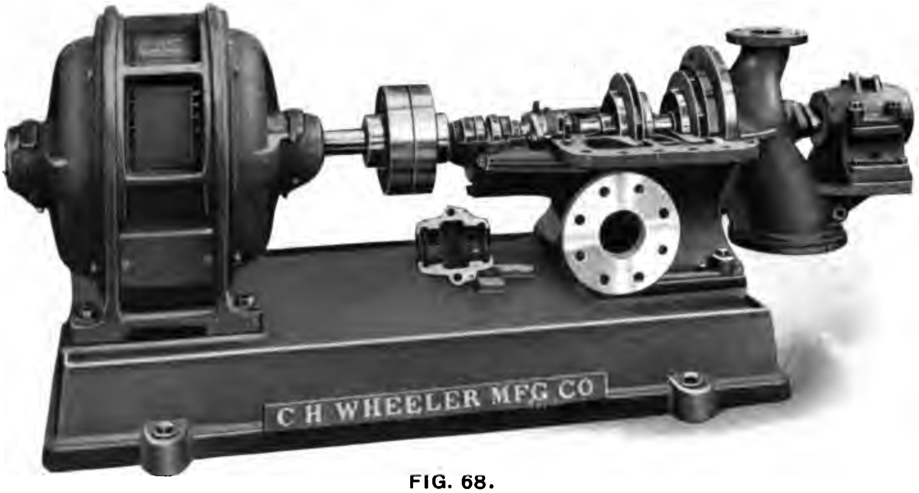


FIG. 68.

Two-stage Centrifugal Hot Well Pump with direct connected Motor. Top half of casing removed.

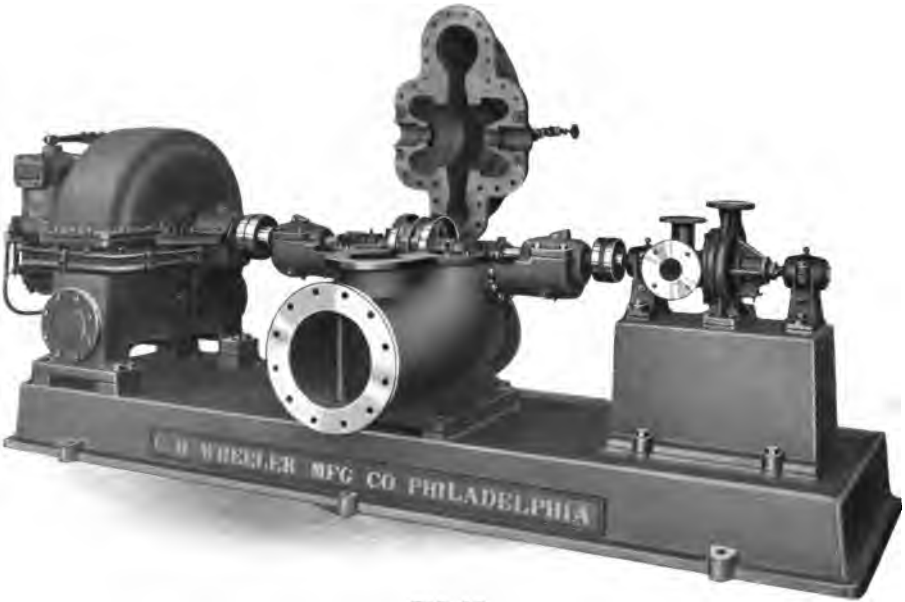


FIG. 69.

Turbine driven Centrifugal Circulating and Hot Well Pumps for Surface Condenser.

Friction losses and the formation of vapor pockets in the pump are minimized by using a suction pipe of large diameter, permitting any air which may enter the hot well with the water to escape against the water flow and return to the hot well, instead of being carried into the pump. The pump operates under a head sufficient to insure continuous flow of water.

Where the continuous operation of the main unit is imperative it is advisable to install two hot well pumps; *i.e.,* to provide one as a spare, not because these pumps cannot be made as reliable as other parts of the equipment, but because of the small first cost of a standby unit.

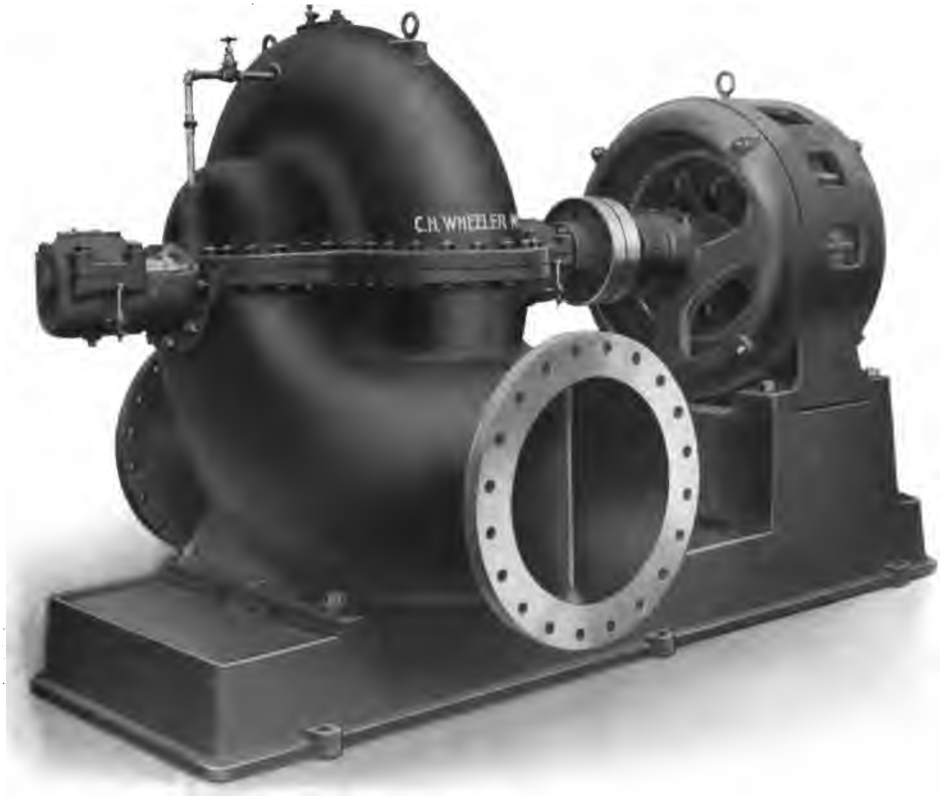


FIG. 70.

High Speed Centrifugal Pump direct connected to induction Motor.

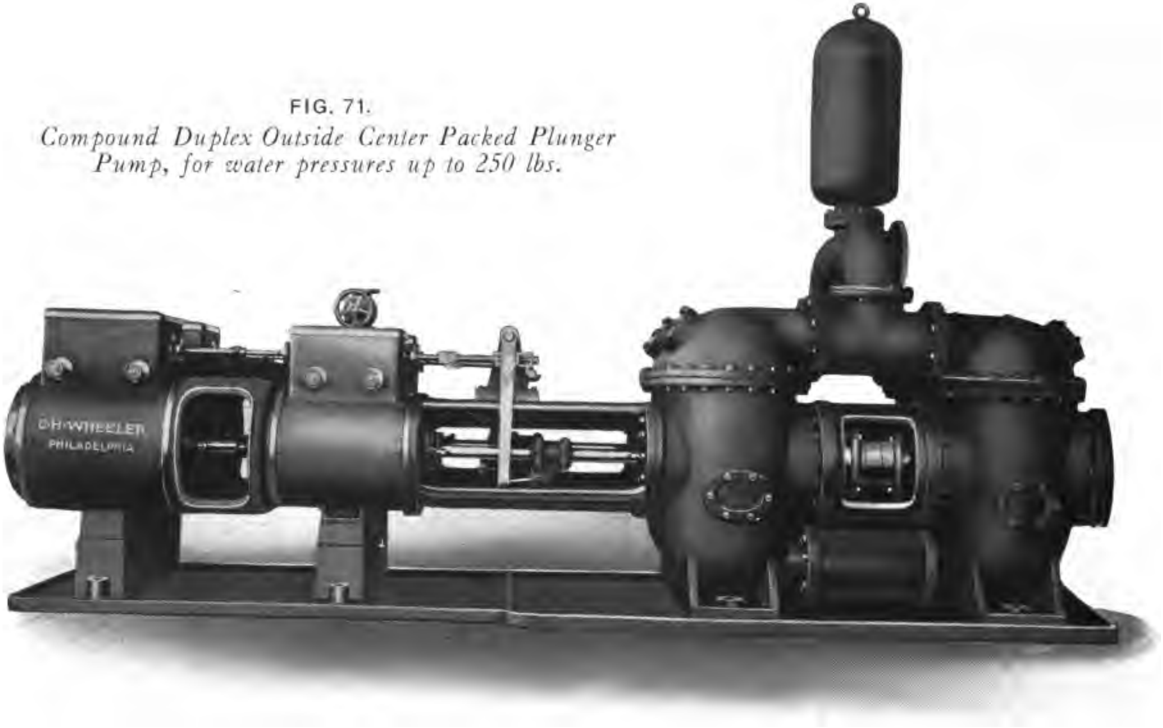


FIG. 71.

Compound Duplex Outside Center Packed Plunger Pump, for water pressures up to 250 lbs.

CHAPTER XI

DIRECT ACTING STEAM PUMPS

The C. H. Wheeler direct acting steam pumps include a full line, not only for condenser service, but for boiler feed, tank filling, fire protection and general requirements. These pumps are built both single and duplex, with simple and compound steam ends. The single pumps are fitted with improved Delamater valve gear which is guaranteed to give full stroke at all speeds. The upper end of the crosshead carries a pair of rollers which act against cams on the rotating stem of the auxiliary valve. The "D" slide valve is controlled by an auxiliary piston, both ends of which are under live steam pressure. The small auxiliary valve already mentioned controls the exhaust to atmosphere from the steam spaces at the end of the auxiliary piston. This arrangement avoids the tendency to stick, which is sometimes encountered when the auxiliary valve controls the live steam admission to the ends of the piston.

The water cylinders of C. H. Wheeler direct acting pumps are brass lined with brass pistons and rods; or, iron pistons and steel rods, depending on whether "brass fitted" or "regular fitted" pumps are specified.

For moderate pressures, packed piston pumps are generally used; for high pressures, outside-packed plungers are preferable.

C. H. Wheeler Pumps are of heavy, rugged construction, with special attention to details whereby wear is minimized and the need for attention and repairs reduced. No attempt is made toward cheap construction, in order to sell at competitive prices; it is a rule of the C. H. Wheeler Manufacturing Company to make the best "only"; and thus eliminate excessive repair and maintenance expenses.

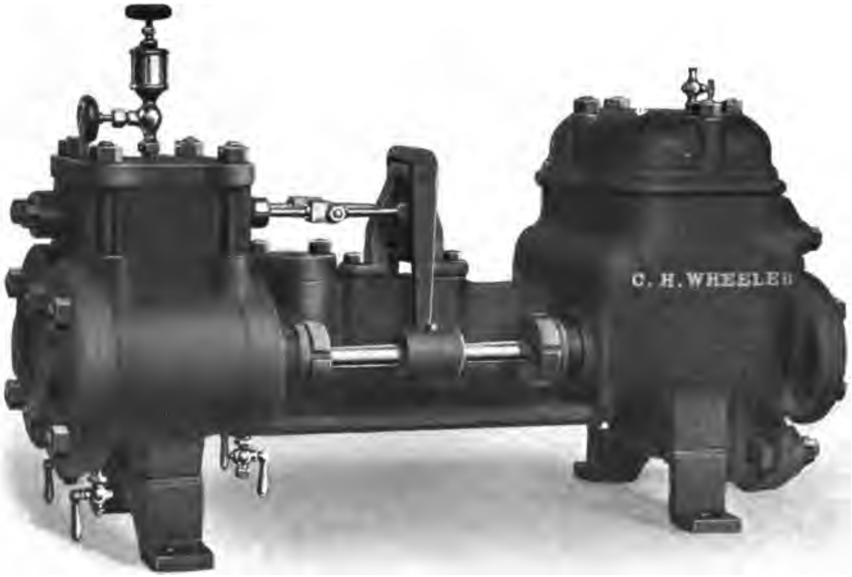


FIG. 72.
Duplex Packed Piston Boiler Feed Pump, for water pressures up to 150 lbs.

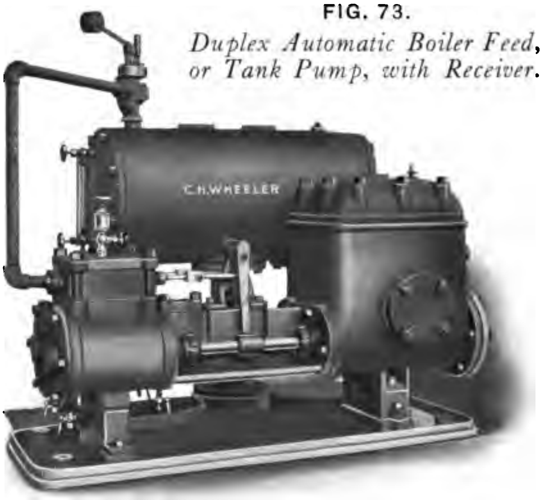


FIG. 73.
Duplex Automatic Boiler Feed, or Tank Pump, with Receiver.

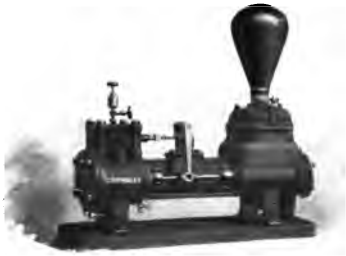


FIG 74.
Auxiliary Underwriter Steam Fire Pump, built to the special specifications of the Associated Factory Mutual Fire Insurance Companies.

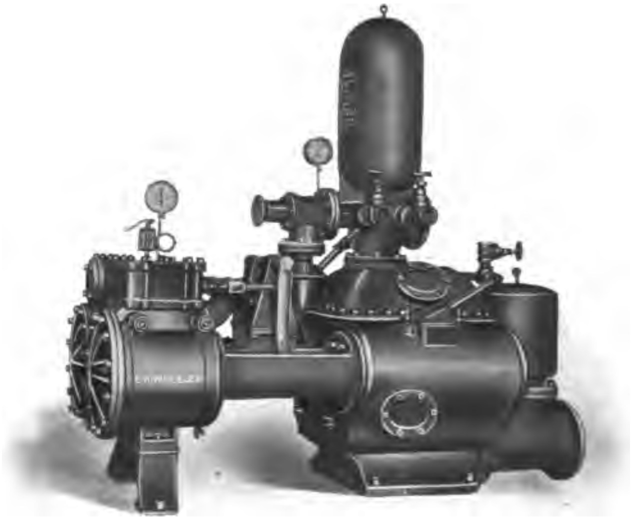
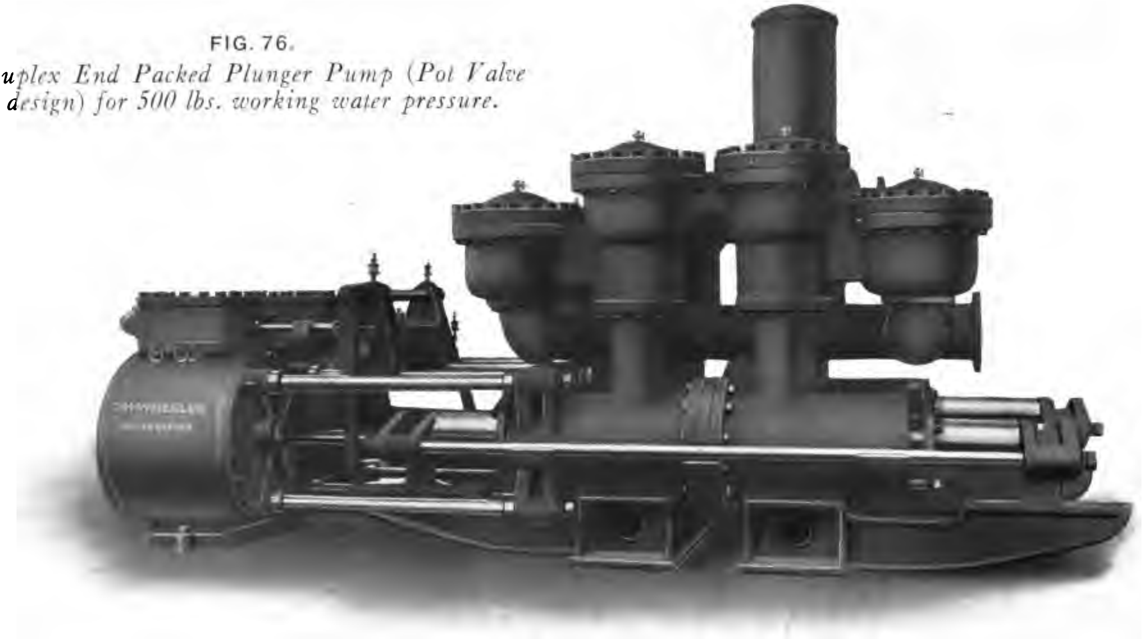


FIG. 75.
Underwriters' Steam Fire Pump. These Pumps are built in accordance with the latest specifications of the Fire Underwriters. Special pamphlet giving sizes and dimensions mailed on request.

FIG. 76.

Duplex End Packed Plunger Pump (Pot Valve design) for 500 lbs. working water pressure.



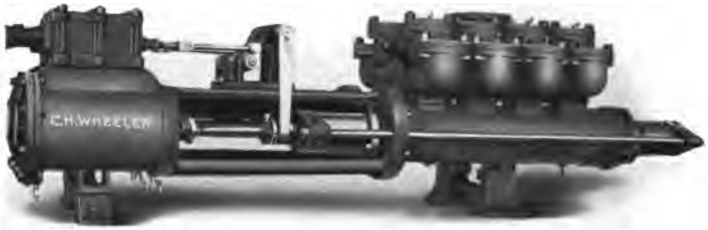


FIG. 77.
Duplex End Packed Plunger Pump (Pot Valve design) for water pressures up to 300 lbs.

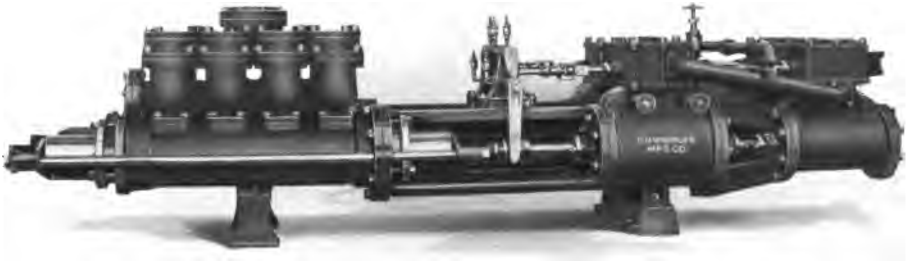


FIG. 78.
Compound Duplex End Packed Plunger Pump (Pot Valve design) for water pressures up to 300 lbs.

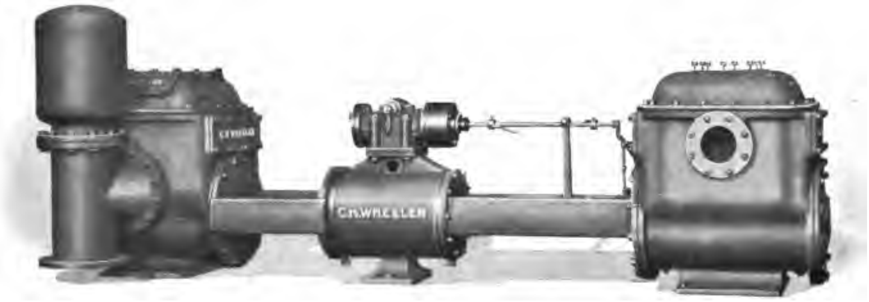


FIG. 79.

Direct Acting Combined Air and Circulating Pump with suction valveless air cylinder.

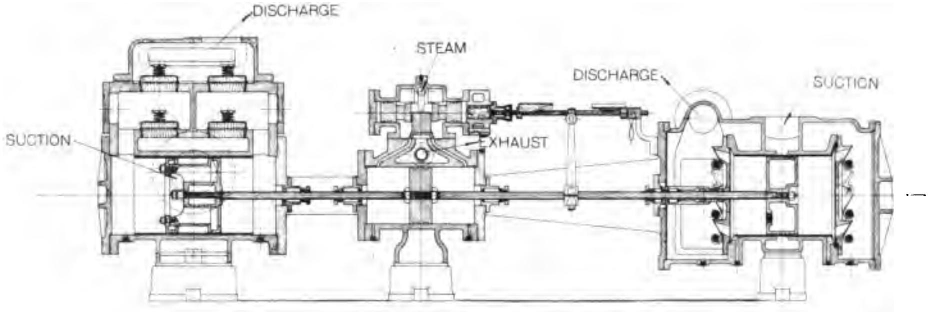


FIG. 80.

Section of Combined Air and Circulating Pump with MULLAN close clearance air cylinder. Suitable for High Vacuum Steam Turbine requirements up to 500 KW.

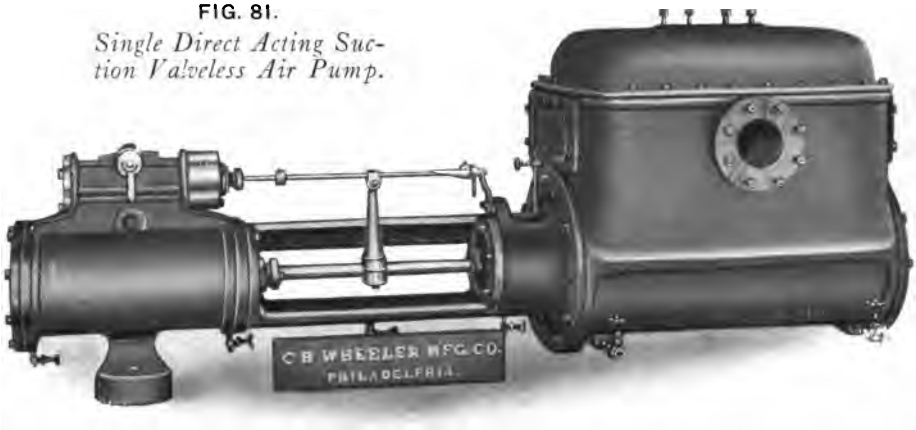


FIG. 81.
Single Direct Acting Suction Valveless Air Pump.

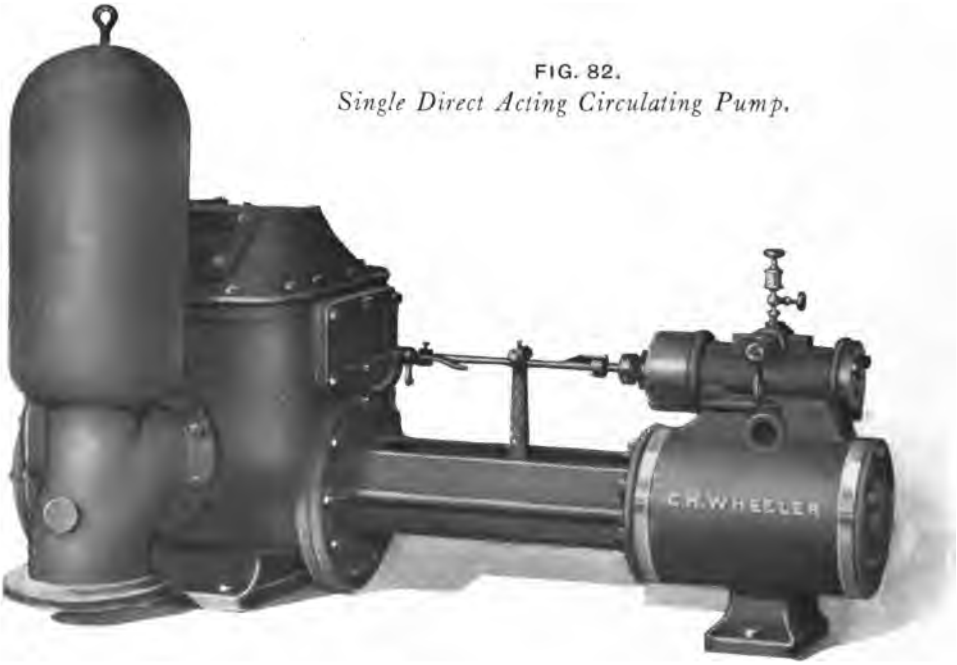


FIG. 82.
Single Direct Acting Circulating Pump.

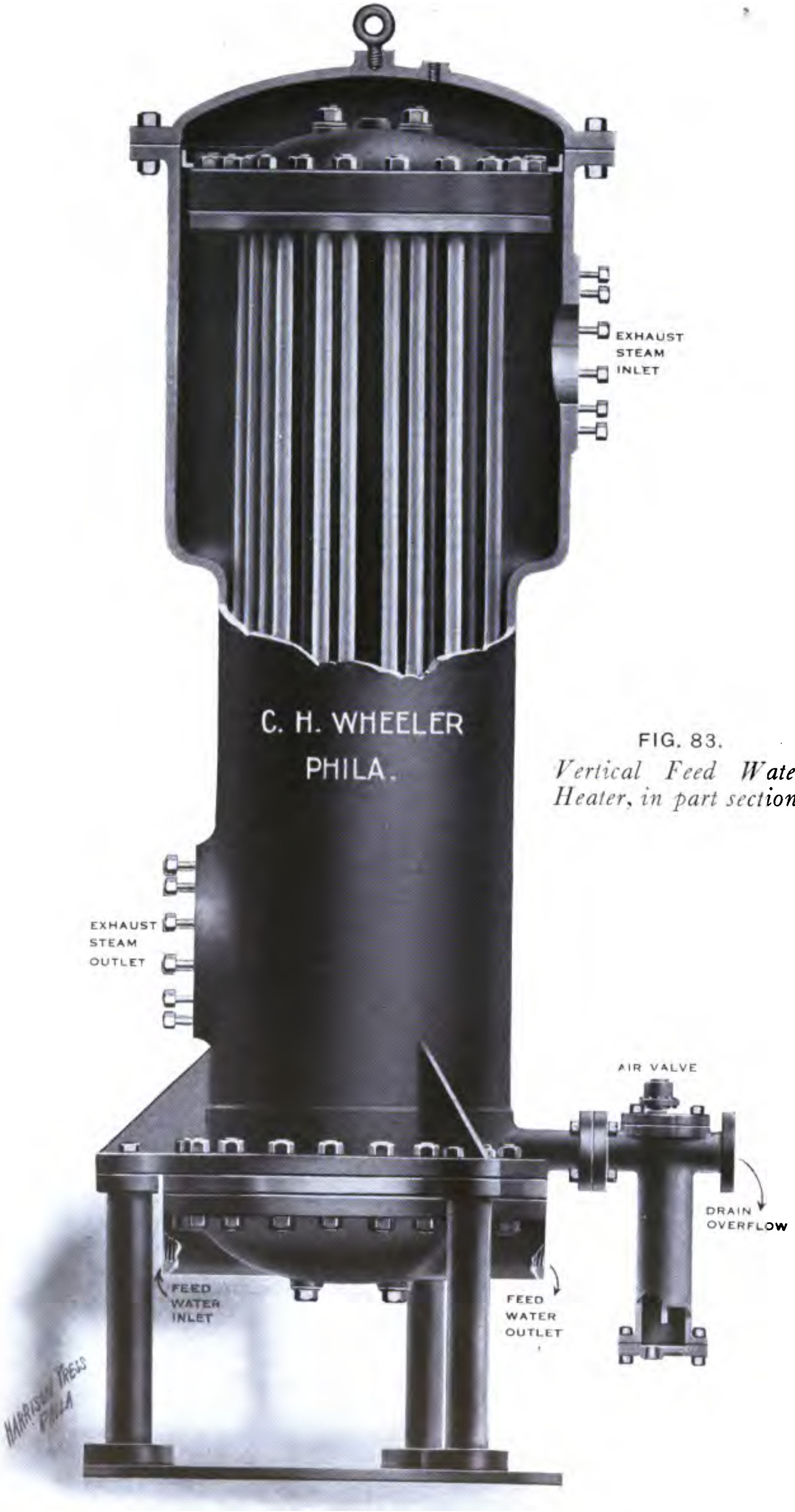


FIG. 83.
Vertical Feed Water Heater, in part section.

CHAPTER XII

FEED WATER HEATERS

Feed Water Heaters are of two types, and known as *Closed* and *Open* Heaters.

The closed type of heater operates like a surface condenser. It consists of a cast iron chamber containing brass or copper tubes through which the water from the hot well, or other source of supply, is forced by the boiler feed pump on its way to the boiler. The space around the tubes is filled with the exhaust steam, either from the main unit (if that operates non-condensing) or from the auxiliary engines or turbines where the main unit operates condensing. The water enters the tubes either cold or at hot well temperature. Where an excess of exhaust steam is provided, the water goes to the boiler within a few degrees of the exhaust steam temperature. When the exhaust steam supply is limited, practically all is condensed in the heater, and its latent heat transferred to the water, thereby determining the resultant temperature of the water.

The open heater consists of a closed chamber, into which the feed water is delivered by a lift pump or other means. In this chamber it overflows a series of trays, and condenses the exhaust steam in the same manner as a jet condenser. The resulting hot water is pumped by the boiler feed pump into the boiler.

Under most conditions the *closed heater* is preferable and for the following reasons:

1. The exhaust from the auxiliaries contains oil, which is never fully eliminated by separators, filters, etc., usually provided for that purpose. The residuum of oil is carried into the boiler, where it impairs the steaming efficiency and fre-

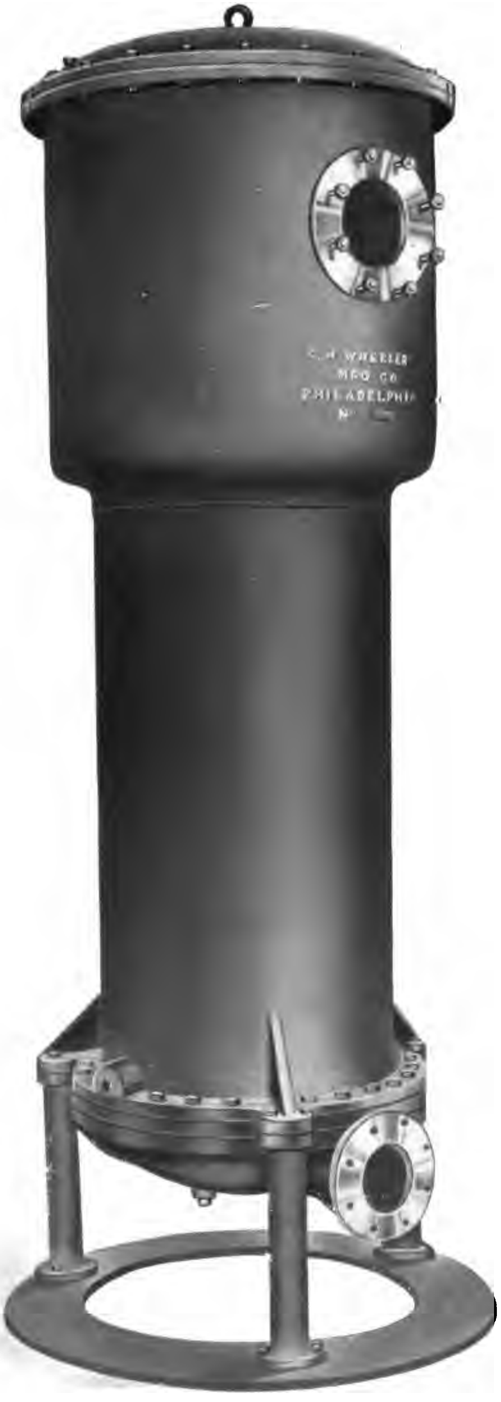


FIG. 84.
Vertical Feed Water Heater.

quently injures the boiler tubes. With a closed heater, no oil can enter the boiler.

2. The closed heater requires only one pump, the boiler feed pump, to deliver the water from the hot well to the boiler. This saves the first cost, operating and maintenance charges of a hot well lift pump; and enables the boiler feed pump to handle practically cold instead of very hot water, with the well-known difficulties incidental to hot water pumping.

In order to intelligently select a feed water heater the conditions attending its operation must be specified as definitely as those of a condenser. The quality and temperature of the feed water obtainable, and the amount of exhaust steam available for heating the feed water should be known. The mere statement that a feed water heater is wanted to supply a boiler of so many horsepower often results in a heater being sold which is unsuitable, and in turn involves needless loss.

C. H. Wheeler Feed Water Heaters

These heaters are of the closed type and furnished to conform to operating conditions. Fig. 83 shows a typical heater in part section. The size and location of openings are arranged to suit the purchaser, provided this can be done without impairing the efficiency of the heater.

The shell is of cast iron, cylindrical in form, with steam distribution chamber at the exhaust inlet. The heads are faced and drilled on close centers; the joints are made watertight with cloth insertion gaskets. The shell is arranged to stand vertically, as the illustrations show; or horizontally, with the steam entering at the top and issuing at the bottom.

Tubes are seamless drawn, of brass or copper, as specified, and having one inch outside diameter, No. 18 BWG. They are expanded into heavy steel tube sheets at each end. The water chambers are of cast iron, with bridges arranged at both ends to give the water from six to twelve passes through the tubes, thereby securing a sufficient velocity of flow to ensure rapid transfer of heat from steam to water. This is an important feature of C. H. WHEELER HEATERS, as the three or four passes commonly used allow the water to flow through the tubes too sluggishly to secure full heat transfer from the surrounding steam. The upper water chamber is free to move with the expansion of the tubes, completely avoiding expansion strains and leakage.

When specified, a siphon seal drain is provided, as shown in Fig. 83, to remove the condensate from the shell without resort to a steam trap. This drain consists of a cast iron chamber, with a vertical division plate operating as a trap. This arrangement provides for the removal of the steam condensed on the tubes, and whatever condensate which may enter with the exhaust steam, or may drain back into the heater shell from the atmospheric pipe. A thermostatic air valve is provided in the top cover of the seal drain, whenever the arrangement of piping renders it desirable, in order to remove the air automatically.

Where the siphon seal drain is not furnished, a tapped opening is provided at the lowest point of the shell for a drain connection.

The water space of the heater is tested to 300 pounds hydrostatic pressure per square inch. The tubes are separately tested to 600 pounds hydrostatic pressure. The steam space is tested to 30 pounds hydrostatic pressure.

These heaters are built in sizes from 100 to 5,000 boiler horsepower, and their performance under specified conditions is fully guaranteed.

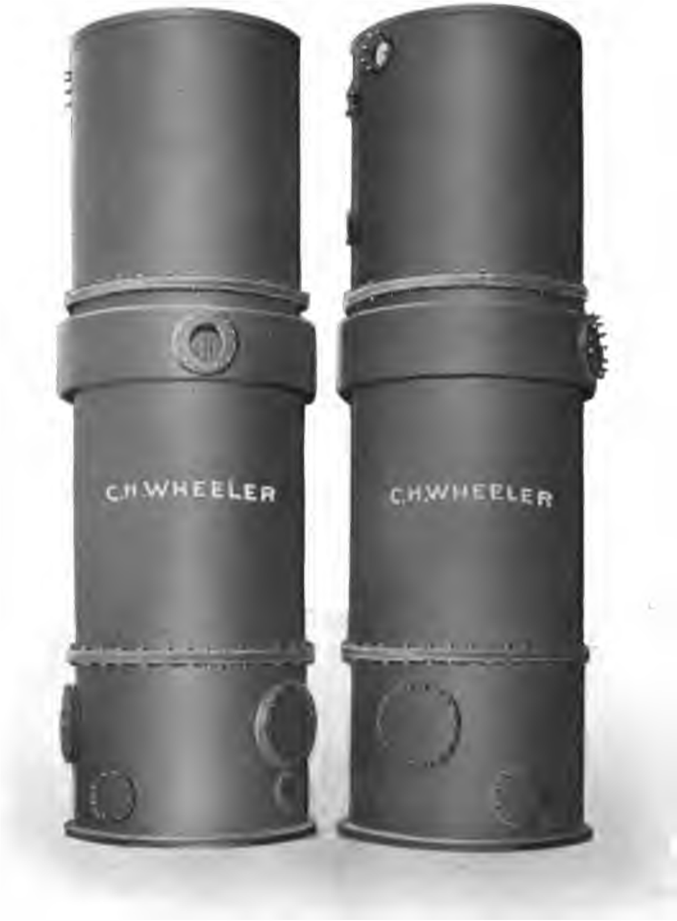
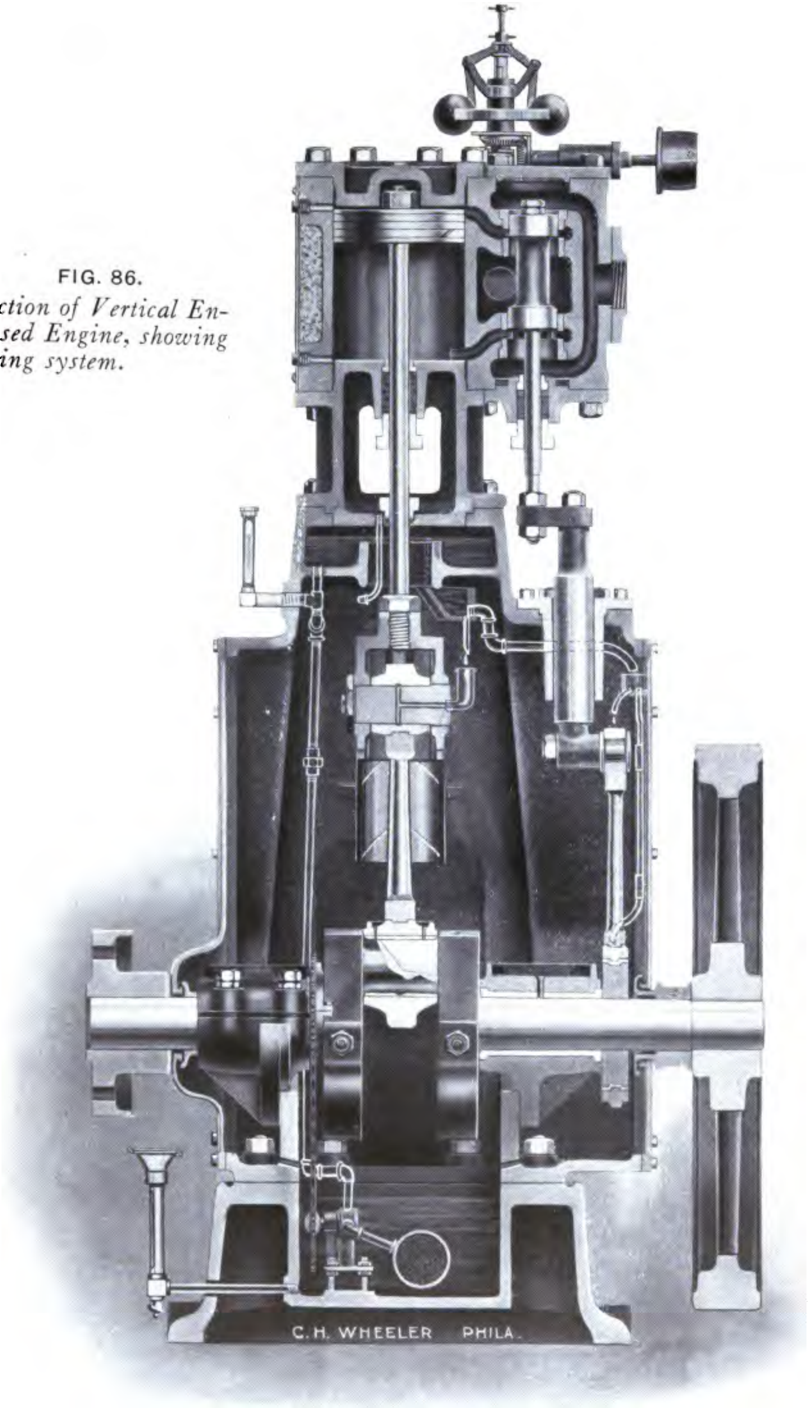


FIG. 85.
Two of the largest Tubular Feed Water Heaters ever built.

FIG. 86.
Section of Vertical Enclosed Engine, showing oiling system.



CHAPTER XIII

ENGINES

C. H. WHEELER Auxiliary Engines are of the vertical enclosed, double-acting type, with balanced piston valve, automatic lubrication, and automatic safety stop throttling governor.

Between the cylinder and the top of the frame is provided a distance piece with a water shed partition and stuffing box in addition to the piston rod stuffing box, see Fig. 86, to prevent any water of condensation which may pass through the cylinder stuffing box from getting into the crankcase and interfering with the lubrication. A similar arrangement, not shown in the illustration, is employed to divert the water of condensation in the valve chest into the cylinder drip, instead of letting it get past the valve rod stuffing box.

The piston valve is of cast iron and connected by means of a valve-stem slide, eccentric rod and strap to an eccentric inside the crankcase. The throttling governor is driven through belt and bevel gears. A spring throwout is provided on the horizontal bevel gear shaft, the arrangement being such as to disengage the gears and cause the governor to drop and close the throttle in case the belt should break or run off the pulley.

The moving parts are completely enclosed within the frame, provided with openings of ample size on the sides and end, insuring ready access to all parts subject to wear. These openings are equipped with oil and dustproof covers.

The crankshaft is forged from high grade open-hearth steel, with integral cranks and crankpin, and balanced by suitable counterweights. The connecting rod is forged, with marine type adjustable boxes. The crosshead is of cast steel with wedge adjusted shoes and the wristpin hardened.

The steam cylinder and valve chest are cast in one piece, carefully insulated with magnesia and covered with Russia

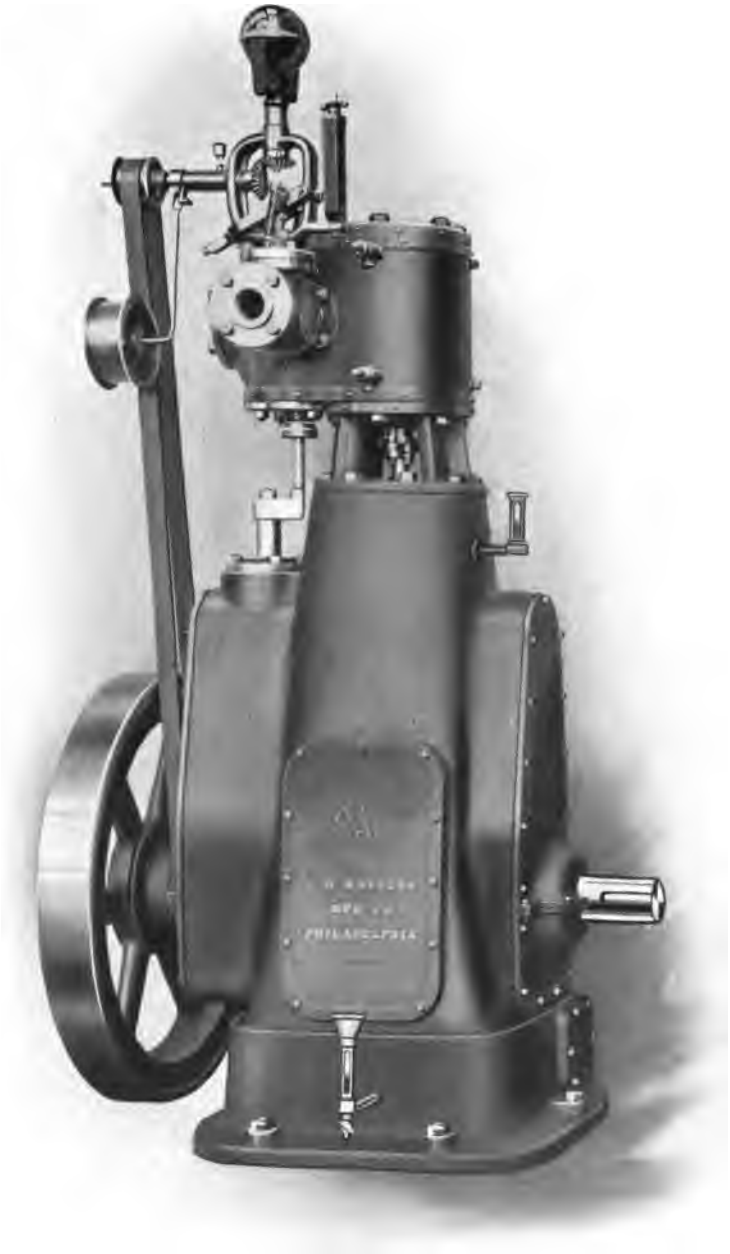


FIG. 87.
Vertical Enclosed Engine.

iron. The cylinder is provided with relief valves of ample size as a protection against possible damage by water. Tapped holes are also provided for indicator connection.

The lubricating system deserves special mention. A chain-driven gear oil pump, submerged in the oil well at the bottom of the crankcase, delivers oil to an overflow basin in the top of the frame, from where the oil overflows to the main bearings and moving parts beneath. An oil "boat" attached to the crosshead delivers oil to the wristpin, and a pocket on the crank end of the connecting rod delivers oil to the crankpin bearing. The main bearings are oiled by splash, oil pockets being provided over them. The valve operating mechanism receive oil from the overflow basin by suitable piping. Oil throwing rings prevent oil from working out of the crankcase along the shaft. The steam cylinder is provided with a sight-feed lubricator.

All engines are tested, indicated and thoroughly inspected before shipment.

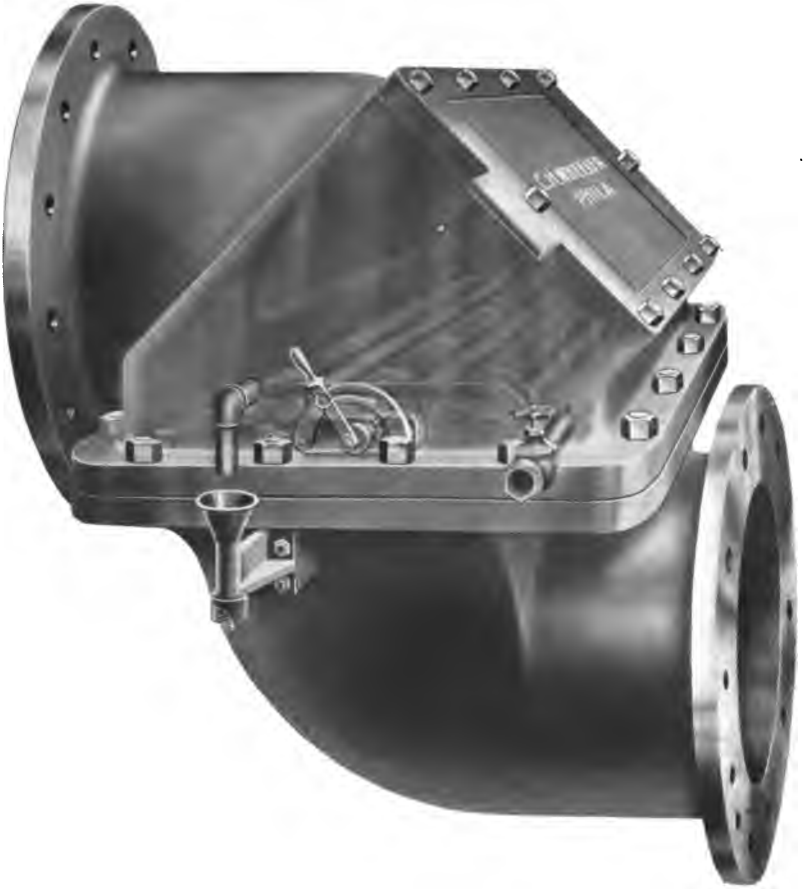


FIG. 88.
Multiflex Atmospheric Exhaust Relief Valve.

CHAPTER XIV

EXHAUST CONNECTIONS

Multiflex Atmospheric Exhaust Relief Valve

This is used with different types of condensers to give a free atmospheric exhaust in case the vacuum fails. The discharge is controlled by a group of valves, each a thin sheet of tempered alloy metal which covers a gridded rectangular opening. The fixed end of each is coiled like a watch spring, and slightly "wound up" to apply the necessary tension to hold the valve closed. The valves are set at such an angle as to discharge the steam without shock and with minimum lift.

As many as possible of these valves are placed together on a brass "deck," and tension applied to all simultaneously by an outside lever, which operates connections to the rocker stems on which the coiled valve ends are mounted.

The light weight and small inertia, of these valves, make it possible to dispense with the complicated dash pot, balance weight, and associated mechanism required to minimize hammering with the old style disc valve.

The entire valve group is water sealed, a small stream being admitted into the space over the valves and overflowing by the pipe and outlet shown.

Expansion Joint

The Expansion Joint provides the necessary flexible link between the turbine and condenser. It is made of corrugated copper, with the ends turned over and fitted into cast iron flange rings accurately faced and drilled.

Owing to the form of the corrugations it can be made very short, thereby minimizing head room. These joints are furnished in sizes and shapes (circular, oval, etc.) to suit the exhaust openings of any make of turbine.

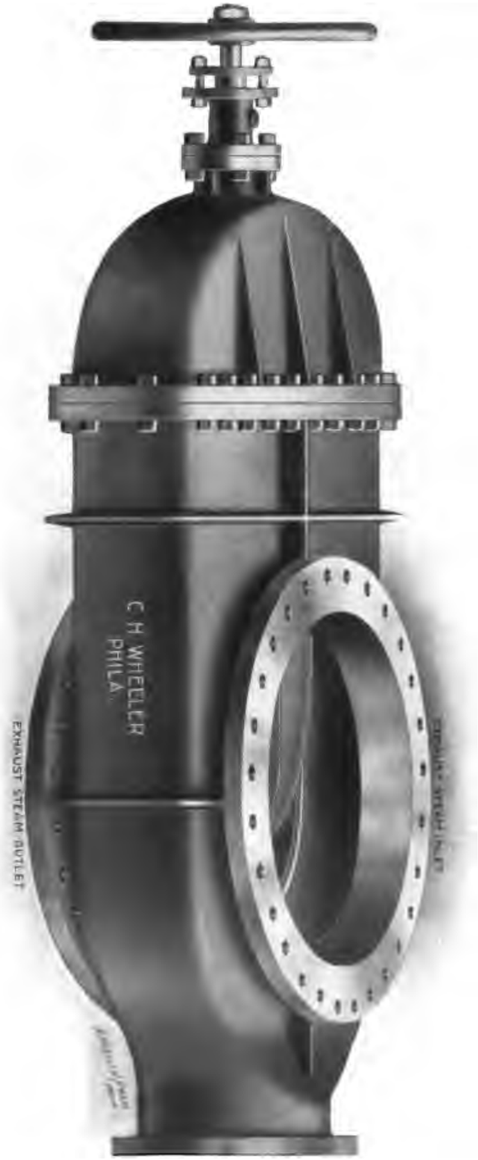


FIG. 89.

Side Outlet Low Pressure Exhaust Gate Valve.

Atmospheric Exhaust Outlet Gate Valve

The above type of valve is used between the turbine and condenser in connection with an atmospheric relief valve. By combining the functions of a gate valve, tee, and atmospheric outlet, it minimizes the head room and often saves the excavation of several feet in a basement in order to place the condenser under the turbine. The valve is of the single gate type, with the face and seat of babbitt metal accurately machined. When open the gate is supported on rollers running on guides which lift it off its seat, thereby making the gate practically frictionless, except at the point of seating where the guides slope downward to permit it reaching its seat. A wedge-shaped guide is further provided to insure positive seating.

The atmospheric relief outlet communicates with the inlet side of the gate, and carries the exhaust steam to the atmospheric relief valve described above.

The valve stem is Tobin bronze, the stuffing box is brass lined and water sealed. The valve is operated by a handwheel, or, when specified, by bevel gear connecting to an extension spindle and floor stand. It may also be motor or hydraulically operated. All valves are tested under 30 pounds water pressure before shipment.

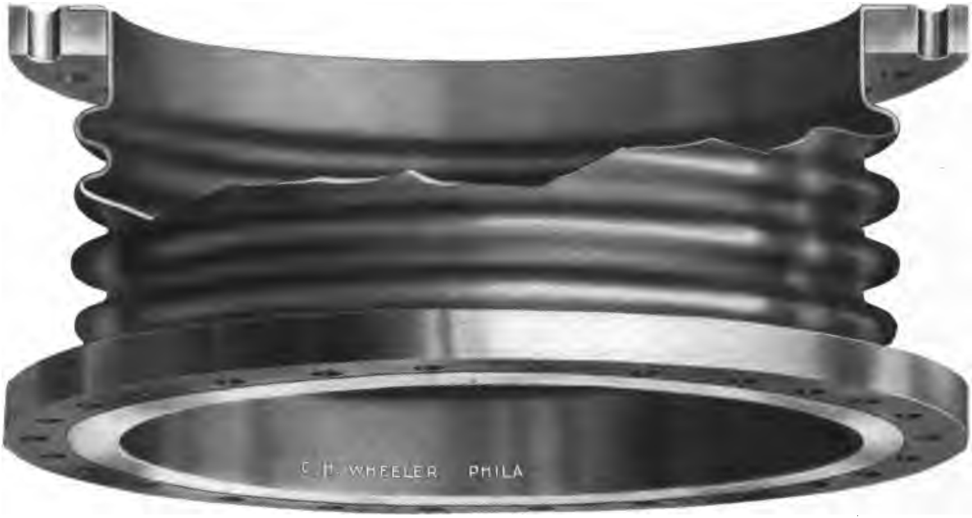


FIG. 90.
Multi-corrugated Copper Expansion Joint.

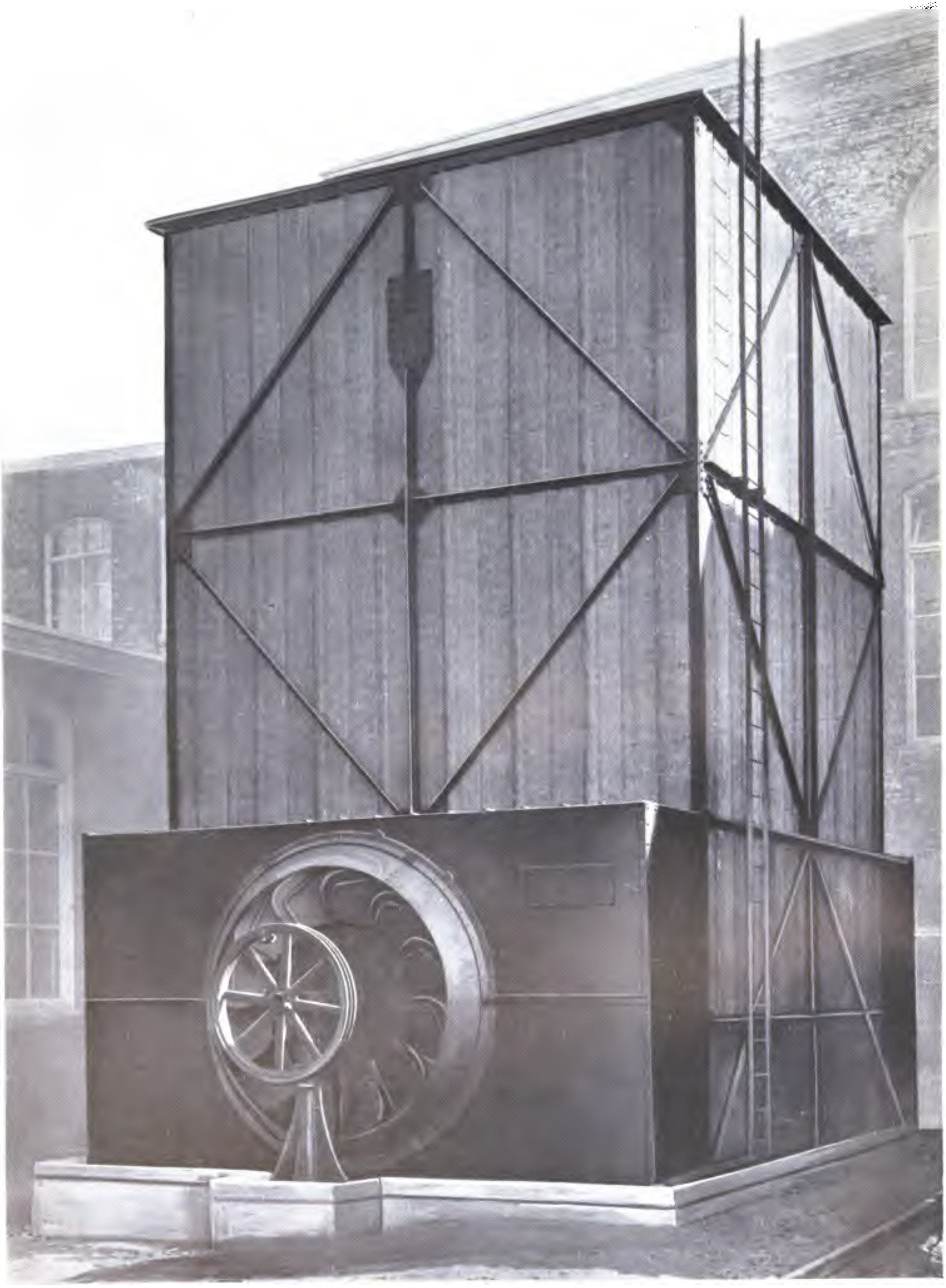


FIG. 91.

Small Forced Draft Tower operating at a Textile Mill.

CHAPTER XV

WATER COOLING TOWERS

Instead of wasting the cooling water discharged from the condenser, it may be used over and over again, provided the heat absorbed during the process of condensing is again extracted. This is the task assigned to the water cooling tower, which, in brief, is an apparatus for cooling water by breaking it up into fine spray and bringing it into contact with a sufficient volume of moving air.

Cooling towers should be used wherever the water supply is limited, also where any considerable amount of sediment forming substance or acids are present in the water available. They may be placed on the ground, though preferably in a location sufficiently elevated or exposed to the breezes (referring especially to the Natural Draft type). Towers are, therefore, frequently placed on the roof, affording the air free access to enter the tower as well as to absorb the vapors contained in the air ascending from the top, saturated with moisture. It may be observed in this connection that the pumping head required with an elevated tower (provided a surface condenser is used) is but slightly increased, owing to the fact that the water columns to and from the tower balance each other; and the only head to be overcome by the pump, in addition to the pipe and condenser friction, is due to the height of the tower above the tank underneath. It is, therefore, obvious that a cooling tower can be employed to advantage with a surface condenser and at small additional operating expense.

The cooling of the water in the tower is accomplished by evaporation, convection and radiation. Of these, evaporation absorbs from 75 to 85 per cent. of the heat; convection or

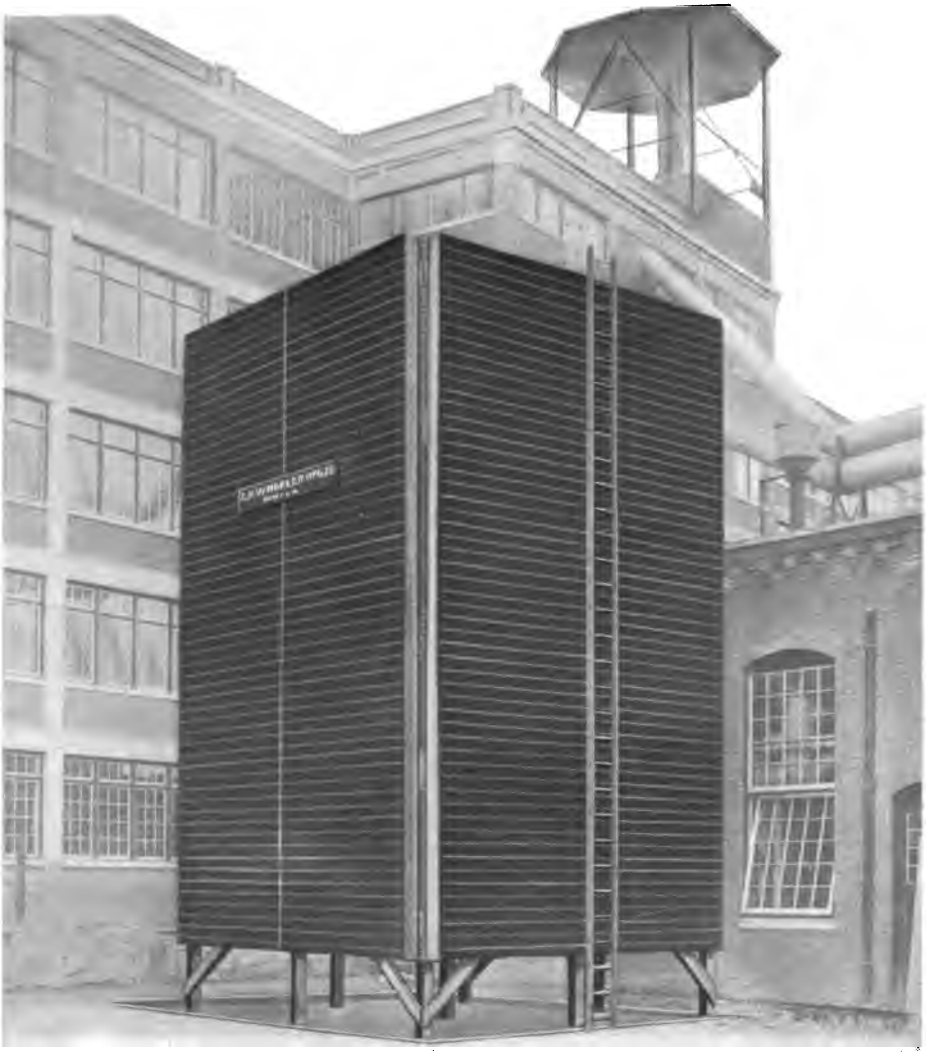


FIG. 92.
Small Natural Draft Cooling Tower at a Shoe Factory.

direct transfer of the heat to the air, comes next, while radiation partly in the tower and partly through the piping accounts for the balance.

Bearing in mind that the latent heat absorbed by the cooling water while condensing one pound of steam in the condenser, must equal the latent heat extracted in the tower when evaporating one pound of water, the quantity of water evaporated will equal the quantity condensed, less the percentage of heat removed by convection and direct radiation. In other words, the cooling tower has to evaporate a quantity of water equaling 75 to 85 per cent. of the weight of steam (corresponding to the feed water) passing through the turbine or engine. This loss must be replaced by a fresh supply.

To accomplish both evaporation and direct transfer of heat an air current is necessary. Each pound of free air absorbs 2.375 B. T. U.'s, while its temperature is raised 10 degrees F. Thus the temperature difference between the water and the entering air limits the heat transfer by convection. For every 1,000 B. T. U.'s of heat transferred in this manner, 422 pounds, or about 5600 cubic feet, of air must be brought in contact with the water and warmed 10 degrees, or 2,800 cubic feet 20 degrees, etc. The same volume of air will absorb an additional and much larger quantity of heat through evaporation. Each pound of air entering the cooling tower at 72 degrees F. with 70 per cent. saturation and leaving saturated at 102 degrees F. will absorb only 7.2 B. T. U.'s by its rise in temperature, but 28.7 B. T. U.'s by the water it evaporates. As the cooling capacity of the air is limited, it is clear that an economical installation must provide means by which a large quantity of air can be brought in contact with the water spray and quickly removed, having been warmed and saturated, to give place to a fresh supply of air.

It is because cooling towers facilitate rapid motion and contact of air with large surfaces of water that they are more efficient, and hence more economical to operate than cooling ponds or spray systems. The latter, owing to their spray distribution on a horizontal plane, cannot utilize to advantage the

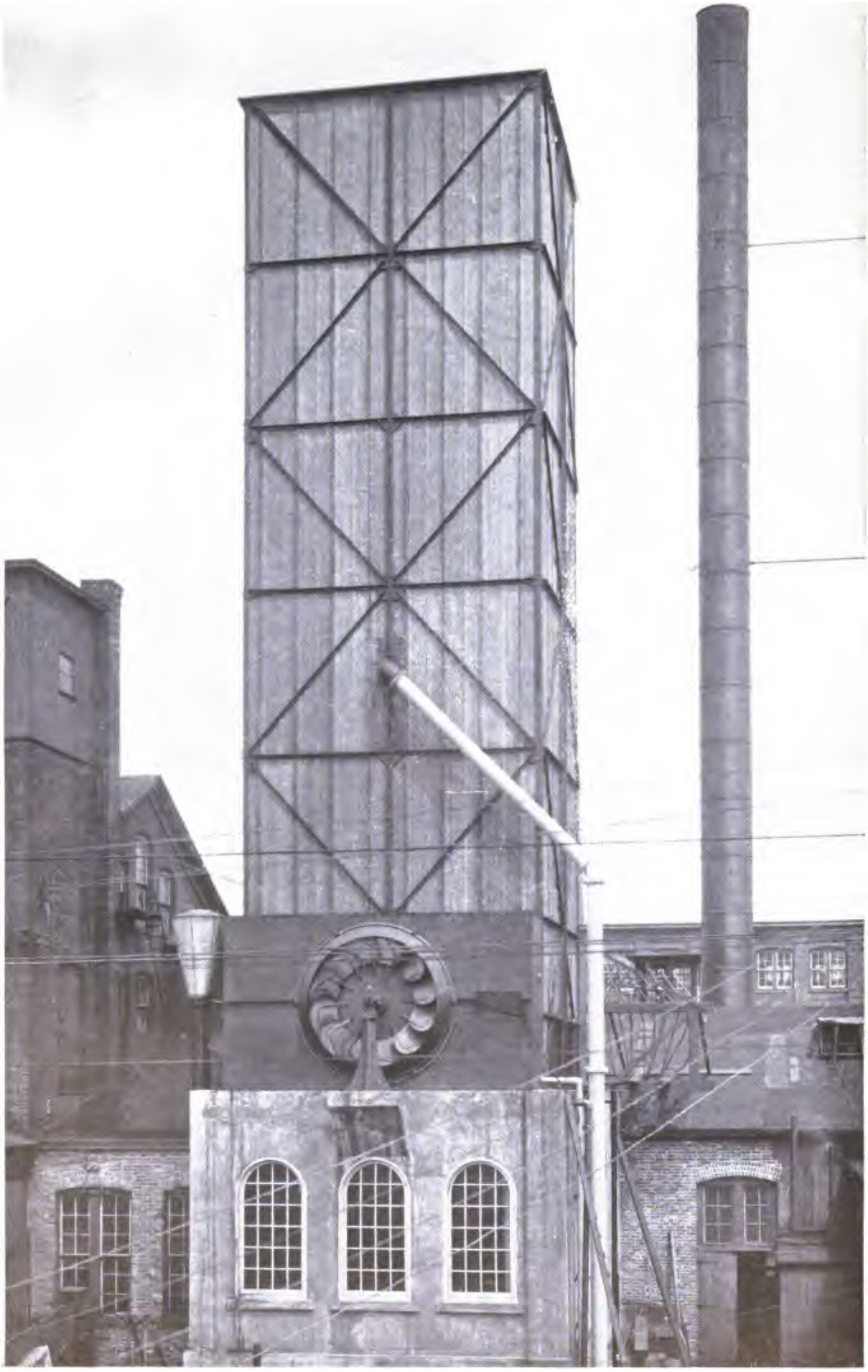


FIG 93.

Special Forced Draft Tower with shell extended to form flue for natural draft.

buoyancy; that is, the tendency to rise of the heated air. Furthermore, the heavy mist drifting from spray ponds make it inadvisable to locate buildings in their proximity. This drawback, which is the result of sluggish evaporation, is avoided with a cooling tower, owing to the rapid motion and large volume of air employed.

The foregoing discloses the relation of the heat to be extracted from the water and the amount of air required to absorb that heat, both directly and by evaporation. Air will evaporate water until saturated; and the amount of moisture absorbed depends upon its initial humidity and temperature together with that of the water. A cooling tower, therefore, should be proportioned for average summer conditions of the atmosphere, as in the winter it will cool the water considerably more and produce a higher vacuum in the condenser.

Evaporation and convection take place on the surface of the water only; it is, therefore, essential to break up the water as thoroughly as possible during its travel from the top of the tower to the tank beneath. This process must be repeated as often as possible, so that no individual drops or streams will remain long undisturbed, as this would permit their surfaces to cool without refrigerating the inner portions. This is accomplished by allowing the water to drip over a series of obstacles, rapidly breaking up and reforming the drops, so that the entire water supply to the tower is converted into slowly falling spray.

Cooling towers may be divided into two distinct types: one of them having open sides to take advantage of the air currents, these are called NATURAL DRAFT TOWERS.

The other type having completely enclosed housings, with fans placed in the base, are designated as FORCED DRAFT TOWERS.

To insure highest efficiency, cooling towers should have a limited width. This is necessary in order to give the air access to the interior cooling surfaces. As an example, a tower 30 feet high and 20 feet wide may extend lengthwise 100 feet or more, thereby presenting the largest surface to the

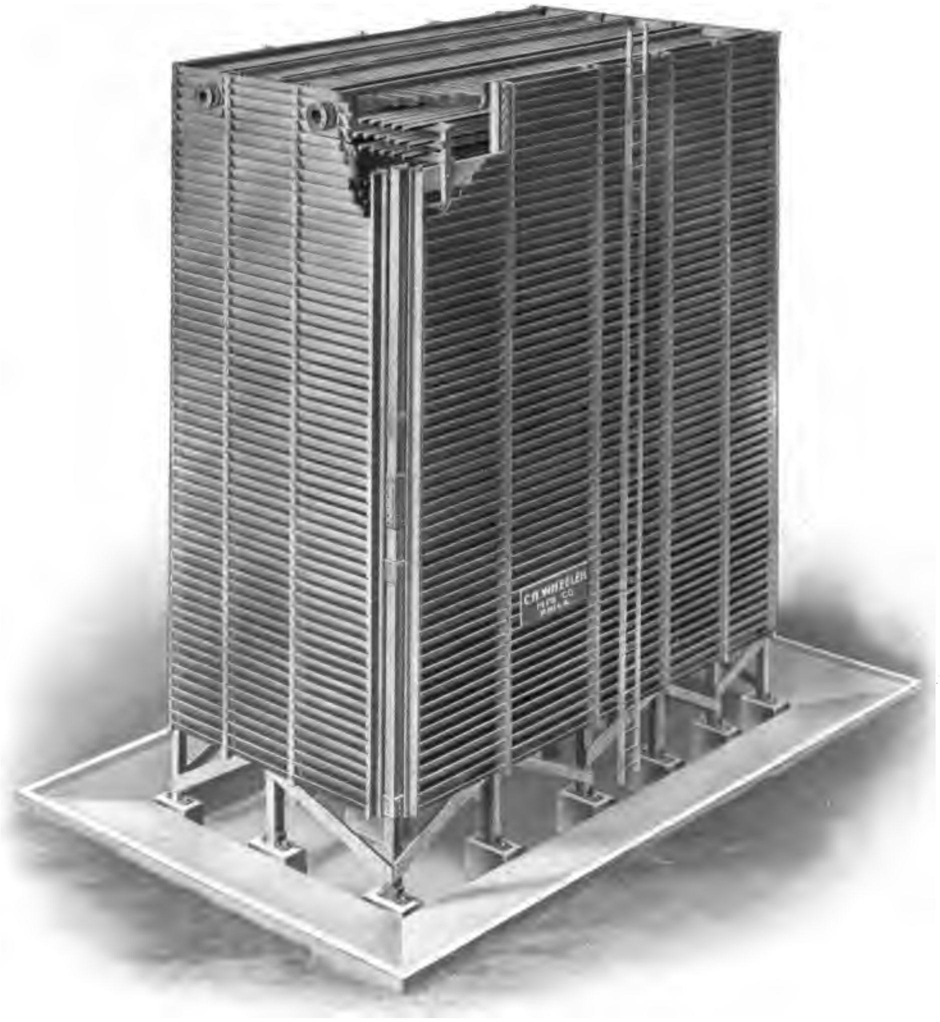


FIG. 94.
C. H. WHEELER-PRATT Natural Draft Water Cooling Tower, showing arrangement of distribution system and cooling surface.

wind. Its location should be so chosen as to expose its greatest surface to the prevailing winds.

Forced draft towers are used where the space is too limited or unsuited for an open tower. They will cool more water per square foot of ground area than the open type. This is due to the increased flow of air supplied by the fans and the accelerated evaporation resulting therefrom.

Natural Draft Towers

With C. H. Wheeler Natural Draft Towers the method of converting water into spray will be seen from Fig. 94. The water is delivered into several feeder troughs at the top of the tower, extending the entire width and connecting with a distribution system consisting of small V-shaped troughs. The latter are perforated and permit the water to overflow in case the perforations should clog. Being open at the top they are readily cleaned while the tower is in operation.

From the distributing troughs the water falls over a series of wood strips made of selected cypress, laid edges up and with the alternate rows staggered so that no water can drop far without striking an obstacle. This construction produces maximum spray effect, affording the water every opportunity to give up its heat.

The racks, supporting the cypress strips, are each secured independently and bolted to substantial uprights of the main framework. Select grade cypress, the only wood "decay proof" against water, is used for the entire interior construction. Instances are recorded where partially submerged cypress piling has endured 200 years without noticeable deterioration; and old cypress water mains have been found in a good state of preservation after centuries of use.

Special attention is given to the arrangement of louvres in Natural Draft Towers, so as to permit free passage of the air in a light breeze, yet arresting the spray in a strong breeze. This is of twofold importance, viz., saving water and preventing inconvenience to adjacent property. When towers are located close to residences, the louvres are more closely spaced

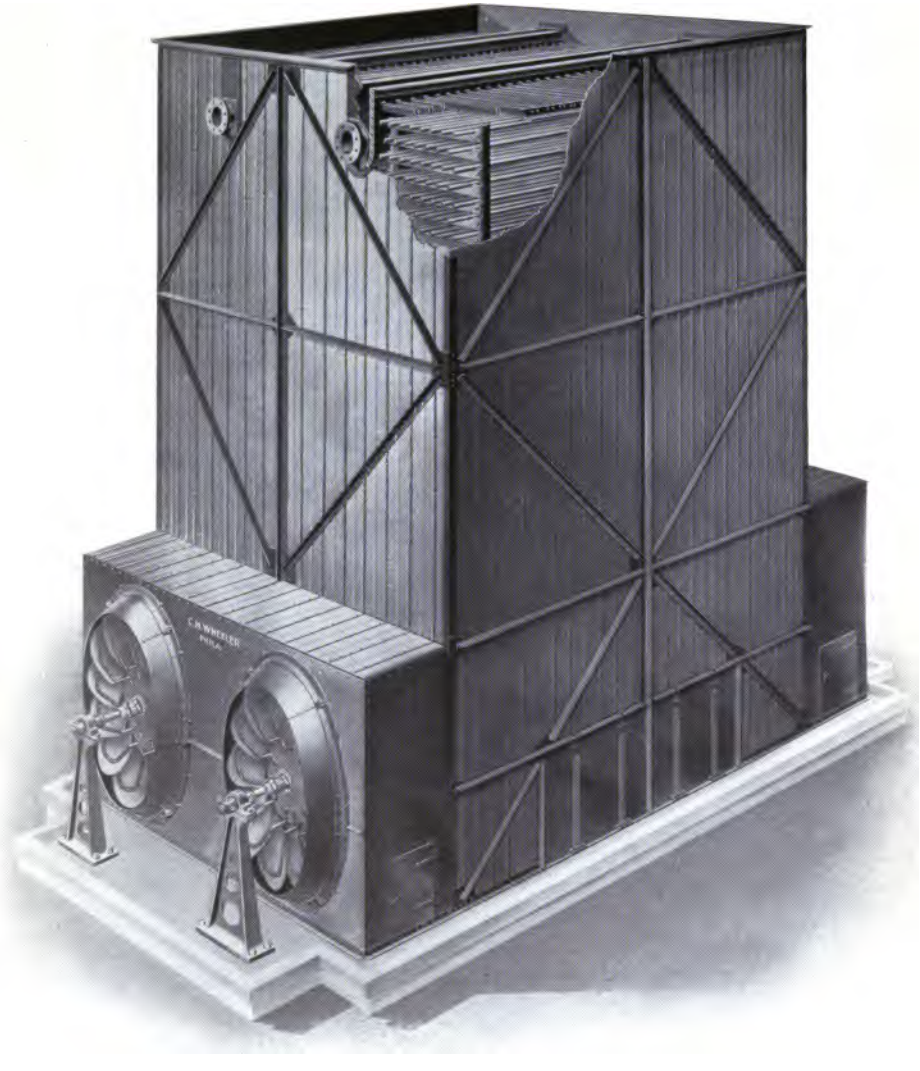


FIG. 95.

C. H. WHEELER-PRATT Forced Draft Water Cooling Tower, showing interior construction.

on the side nearest the adjacent property; thereby rendering the spray negligible.

The main framework and louvres consist of long leaf yellow pine. They are waterproofed by thorough impregnating, under heat, with carbolineum paint, a product resembling creosote, but with higher preservative qualities.

Forced Draft Towers

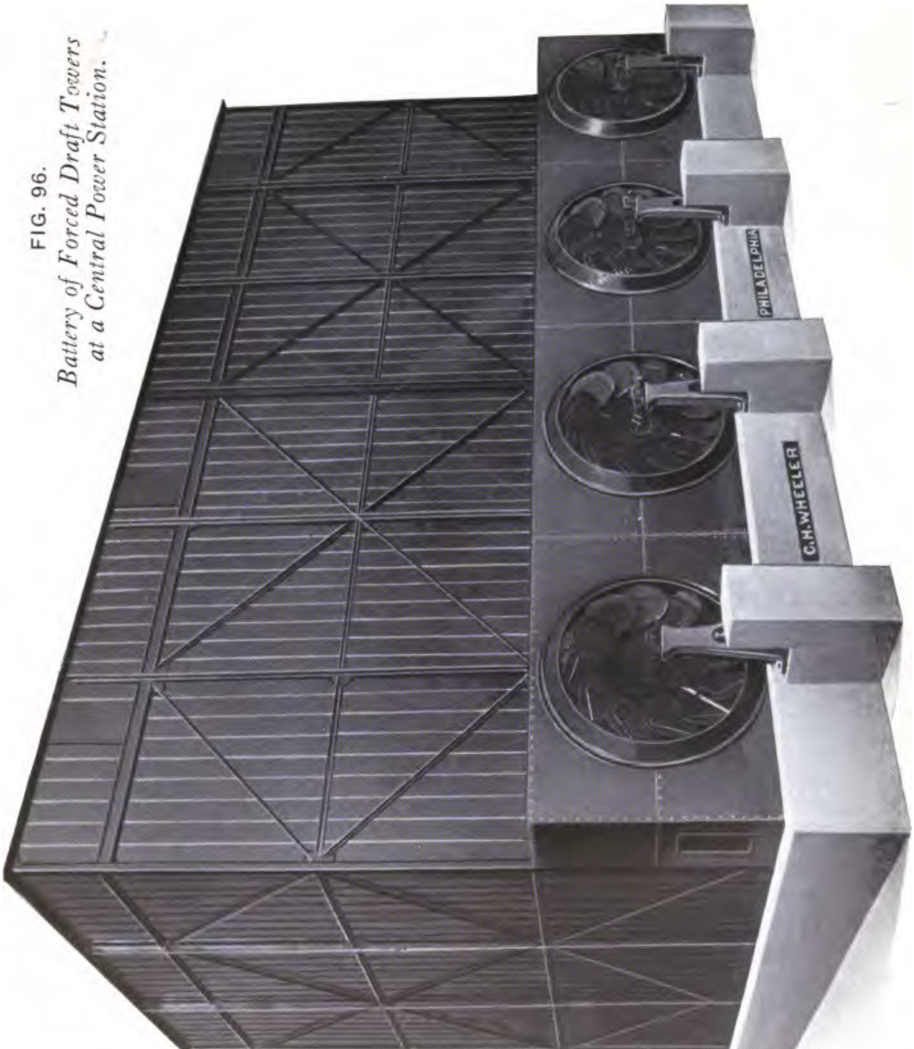
C. H. WHEELER Forced Draft Towers are similar to the open type as regards the interior construction. The sides are closed; and the air is delivered by fans, two of which are placed on one shaft at opposite sides of the tower. See Fig. 95. The housing of these towers is generally covered with metal sheets, protected by several coats of asbestos and asphaltum applied by a special process, the strength of which and resistance to corrosion are well known. The siding may also be of galvanized plating, or of any rust resisting "pure iron" sheeting. The shell and framework of all C. H. WHEELER Forced Draft Towers are entirely separated from the interior construction. so that one may be renewed without disturbing the other.

An important feature of C. H. WHEELER Forced Draft Towers is the provision for painting all portions of the metal siding and its supporting framework. The latter is of heavy structural steel, to which the siding is bolted on the inside, thereby protecting the framework from corrosion by the water in the tower. Every part of the frame can be reached and painted from the outside. The inner surfaces of the siding are made accessible, by removing some of the adjacent cypress strips inside of the tower, these being laid loosely on horizontal racks. A painter can start at the top of the tower and work downward, by simply removing and replacing the wood strips, using them as a platform on which to stand. The importance of this feature, facilitating the proper maintenance at small expense, will be appreciated when it is considered that with some types it is practically impossible to paint the inner surfaces after the tower is once put in operation.

The fans are of special design, to meet the requirements of low pressure and large volume of air. The blades are

FIG. 96.

Battery of Forced Draft Towers at a Central Power Station.



double galvanized and riveted to braces held by a central disc, which fills the ineffective portion of the fan. The cast iron hub of the disc is split and clamped tightly on the shaft by bolts. Hollow steel tubing is used for the fan shaft with diameters ranging from 6 inches to 8 inches. The fans are enclosed in hoods projecting at each end of tower and fully protected inside from water spray. Each fan is carried between two roller bearings in self-aligning ball and socket mountings, the inner bearing being accessible through doors in the hoods. There is no bearing in the tower exposed to the water. With very large towers, when a central bearing is necessary, the entire shaft from end to end is covered by a cypress hood, and the central bearing provided with ring oiling device including oil supply pipe and overflow carried to the outside of the tower, thereby providing easy lubrication while insuring that no oil will get into the cooling water.

RELATIVE HUMIDITY TABLE

BAROMETER 30″

DIFFERENCE BETWEEN DRY AND WET THERMOMETERS

AIR TEMPERATURES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	AIR TEMPERATURES
30	100	89	78	67	57	47	36	26	17	7																				**30**
35	100	91	82	73	65	54	45	37	28	19	12	3																		**35**
40	100	92	84	76	68	60	53	45	38	30	22	16	8	1																**40**
45	100	92	85	78	71	64	58	51	44	38	32	25	19	13	7	1														**45**
50	100	93	87	80	74	67	61	55	50	44	38	33	27	22	16	11	6	1												**50**
55	100	94	88	82	76	70	65	59	54	49	43	39	34	29	24	19	16	10	6	1										**55**
60	100	94	89	84	78	73	68	63	58	53	48	44	39	34	30	26	22	18	14	10	6	2								**60**
65	100	95	90	85	80	75	70	65	61	56	52	48	44	39	35	31	28	24	20	17	13	10	6	3						**65**
70	100	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36	33	29	26	23	19	16	13	10	7	4	1			**70**
75	100	95	91	87	82	78	74	70	66	62	58	55	51	47	44	40	37	34	31	27	24	21	19	16	13	10	7	5	2	**75**
80	100	96	92	87	83	79	75	72	68	64	61	57	54	51	47	44	41	38	35	32	29	26	23	20	18	15	13	10	8	**80**
85	100	96	92	88	84	80	77	73	70	66	63	60	56	53	50	47	44	41	38	36	33	30	28	25	22	20	17	15	13	**85**
90	100	96	92	88	85	81	78	75	71	68	65	62	59	56	53	50	47	44	41	39	36	34	32	29	26	24	22	20	17	**90**
95	100	96	93	89	86	82	79	76	72	69	66	63	60	58	55	52	49	47	44	42	39	37	35	32	30	28	25	23	21	**95**
100	100	97	93	90	86	83	80	77	74	71	68	65	62	59	57	54	51	49	47	44	42	39	37	35	33	31	29	27	25	**100**
105	100	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51	49	46	44	42	40	38	35	33	31	30	28	**105**
110	100	97	94	90	87	84	81	78	76	73	70	67	65	62	60	57	55	53	50	48	46	44	42	40	38	36	34	32	30	**110**
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	

FIG. 97.

Large Cooling Tower on the roof of a Soap Factory.

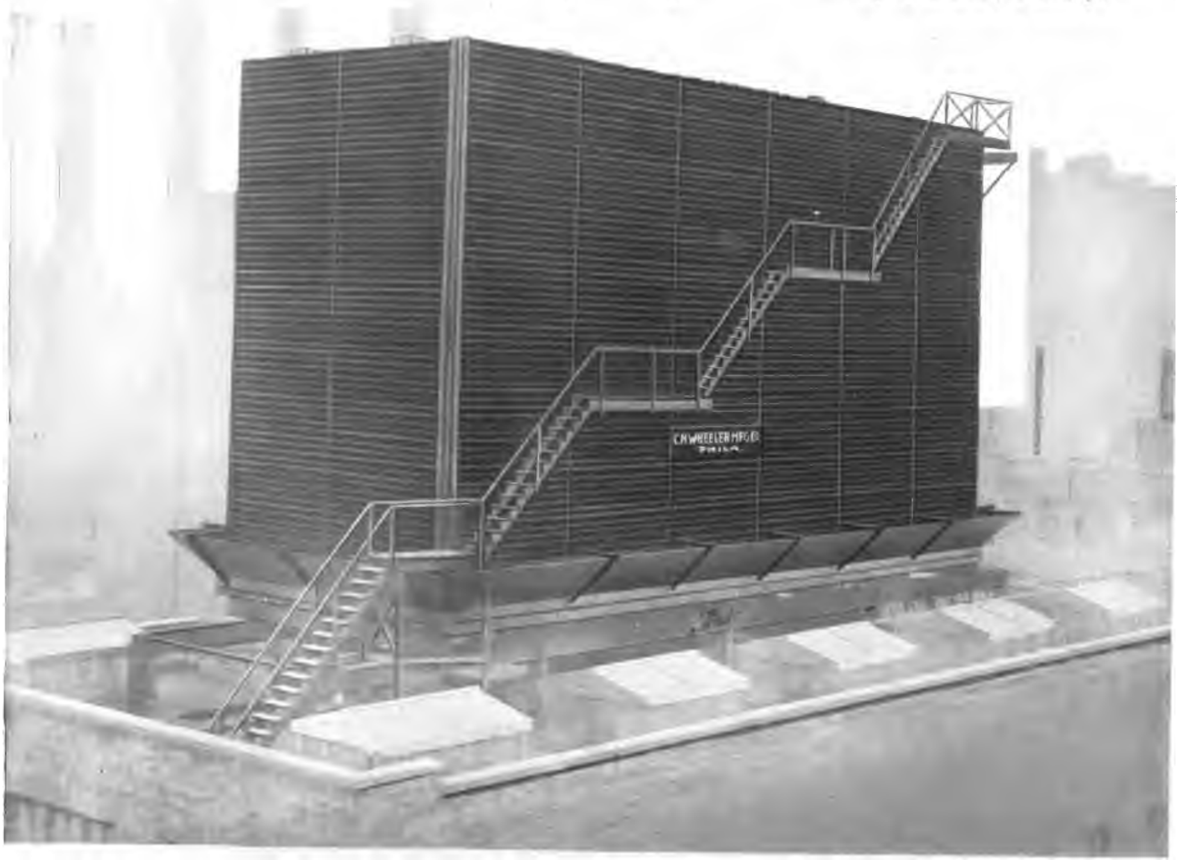


FIG. 98.

Large Cooling Tower on the roof of a Textile Mill.

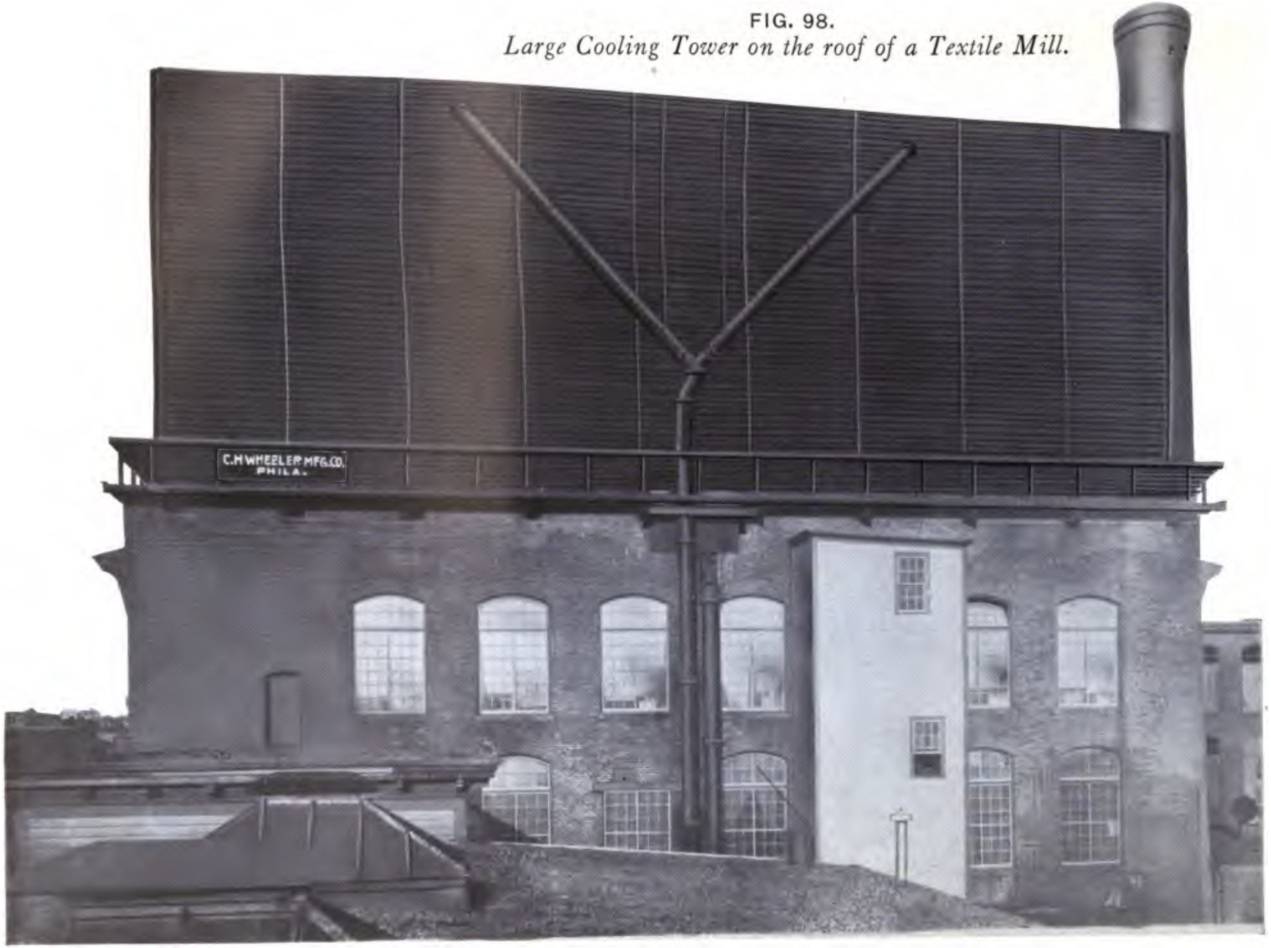


TABLE I.

Properties of Saturated Steam from 32° to 212° F.

Temp. ° F.	Vacuum in in. of mercury referred to 30" Bar.	Absolute pressure in. of mercury.	Specific volume cubic ft. per lb.	Temp. ° F.	Vacuum in in. of mercury referred to 30" Bar.	Absolute pressure in. of mercury.	Specific volume cubic ft. per lb.
32	29.819	.181	3294	65	29.376	.624	1024
33	29.812	.188	3170	66	29.354	.646	991
34	29.804	.196	3052	67	29.331	.669	959
35	29.796	.204	2938	68	29.308	.692	928
36	29.788	.212	2829	69	29.284	.716	899
37	29.779	.221	2725	70	29.259	.741	871
38	29.771	.229	2626	71	29.234	.766	843
39	29.761	.239	2530	72	29.208	.792	817
40	29.752	.248	2438	73	29.181	.819	792
41	29.742	.258	2350	74	29.153	.847	767
42	29.732	.268	2266	75	29.125	.875	743
43	29.721	.279	2185	76	29.095	.905	720
44	29.710	.290	2107	77	29.065	.935	698
45	29.699	.301	2033	78	29.034	.966	677
46	29.687	.313	1961	79	29.002	.998	657
47	29.675	.325	1892	80	28.968	1.032	636.8
48	29.663	.337	1826	81	28.934	1.066	617.5
49	29.650	.350	1763	82	28.899	1.101	598.7
50	29.637	.363	1702	83	28.863	1.137	580.5
51	29.623	.377	1643	84	28.826	1.174	562.9
52	29.609	.391	1586	85	28.788	1.212	545.9
53	29.594	.406	1532	86	28.749	1.251	529.5
54	29.579	.421	1480	87	28.708	1.292	513.7
55	29.563	.437	1430	88	28.666	1.334	498.4
56	29.547	.453	1381	89	28.624	1.376	483.6
57	29.530	.470	1335	90	28.580	1.420	469.3
58	29.513	.487	1291	91	28.535	1.465	455.5
59	29.495	.505	1249	92	28.489	1.511	442.2
60	29.477	.523	1208	93	28.441	1.559	429.4
61	29.458	.542	1168	94	28.392	1.608	417.0
62	29.439	.561	1130	95	28.341	1.659	405.0
63	29.419	.581	1093	96	28.290	1.710	393.4
64	29.398	.602	1058	97	28.237	1.763	382.2

TABLE I.

Properties of Saturated Steam from 32° to 212° F.

(*Continued*)

Temp. ° F.	Vacuum in in. of mercury referred to 30" Bar.	Absolute pressure in. of mercury.	Specific volume cubic ft. per lb	Temp. ° F	Vacuum in in. of mercury referred to 30" Bar.	Absolute pressure in. of mercury.	Specific volume cubic ft. per lb.
98	28.183	1.817	371.4	132	25.23	4.77	149.4
99	28.127	1.873	360.9	133	25.10	4.90	145.8
100	28.070	1.930	350.8	134	24.97	5.03	142.2
101	28.011	1.989	341.0	135	24.84	5.17	138.7
102	27.951	2.049	331.5	136	24.70	5.30	135.4
103	27.889	2.111	322.2	137	24.56	5.44	132.1
104	27.825	2.175	313.3	138	24.41	5.59	128.9
105	27.759	2.241	304.7	139	24.26	5.74	125.8
106	27.692	2.308	296.4	140	24.11	5.89	122.8
107	27.623	2.377	288.3	141	23.96	6.04	119.9
108	27.550	2.450	280.5	142	23.81	6.19	117.1
109	27.478	2.522	272.9	143	23.64	6.36	114.3
110	27.404	2.596	265.5	144	23.47	6.53	111.6
111	27.328	2.672	258.3	145	23.31	6.69	109.0
112	27.250	2.750	251.4	146	23.14	6.86	106.5
113	27.170	2.830	244.7	147	22.96	7.04	104.0
114	27.088	2.912	238.2	148	22.78	7.22	101.6
115	27.005	2.995	231.9	149	22.60	7.40	99.2
116	26.919	3.081	225.8	150	22.42	7.58	96.9
117	26.830	3.170	219.9	155	21.43	8.57	86.4
118	26.739	3.261	214.1	160	20.32	9.68	77.2
119	26.647	3.353	208.5	165	19.11	10.89	69.1
120	26.553	3.447	203.1	170	17.77	12.23	62.0
121	26.456	3.544	197.9	175	16.30	13.70	55.7
122	26.355	3.645	192.8	180	14.67	15.33	50.15
123	26.253	3.747	187.9	185	12.89	17.11	45.25
124	26.149	3.851	183.1	190	10.93	19.07	40.91
125	26.040	3.960	178.4	195	8.80	21.20	37.04
126	25.931	4.069	173.9	200	6.47	23.53	33.60
127	25.820	4.180	169.6	205	3.93	26.07	30.53
128	25.706	4.294	165.3	210	1.16	28.84	27.80
129	25.589	4.411	161.1	212	0.00	30.00	26.79
130	25.48	4.52	157.1				
131	25.35	4.65	153.2				

TABLE II.

Mean Barometric Pressures Corresponding to Altitudes from 100 to 4900 ft. above Sea Level

Feet	Inches	Feet	Inches
0	30.00	2500	27.26
100	29.88	2600	27.17
200	29.76	2700	27.05
300	29.64	2800	26.95
400	29.52	2900	26.85
500	29.40	3000	26.74
600	29.29	3100	26.65
700	29.18	3200	26.55
800	29.08	3300	26.45
900	28.97	3400	26.35
1000	28.86	3500	26.26
1100	28.76	3600	26.16
1200	28.65	3700	26.06
1300	28.54	3800	25.96
1400	28.44	3900	25.85
1500	28.34	4000	25.75
1600	28.23	4100	25.64
1700	28.14	4200	25.55
1800	28.04	4300	25.46
1900	27.94	4400	25.37
2000	27.82	4500	25.26
2100	27.70	4600	25.16
2200	27.58	4700	25.07
2300	27.47	4800	24.98
2400	27.36	4900	24.88

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